ASTRONOMY

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Computing the Cosmos

Do Comets Become Asteroids?

Getting to Know Variable Stars

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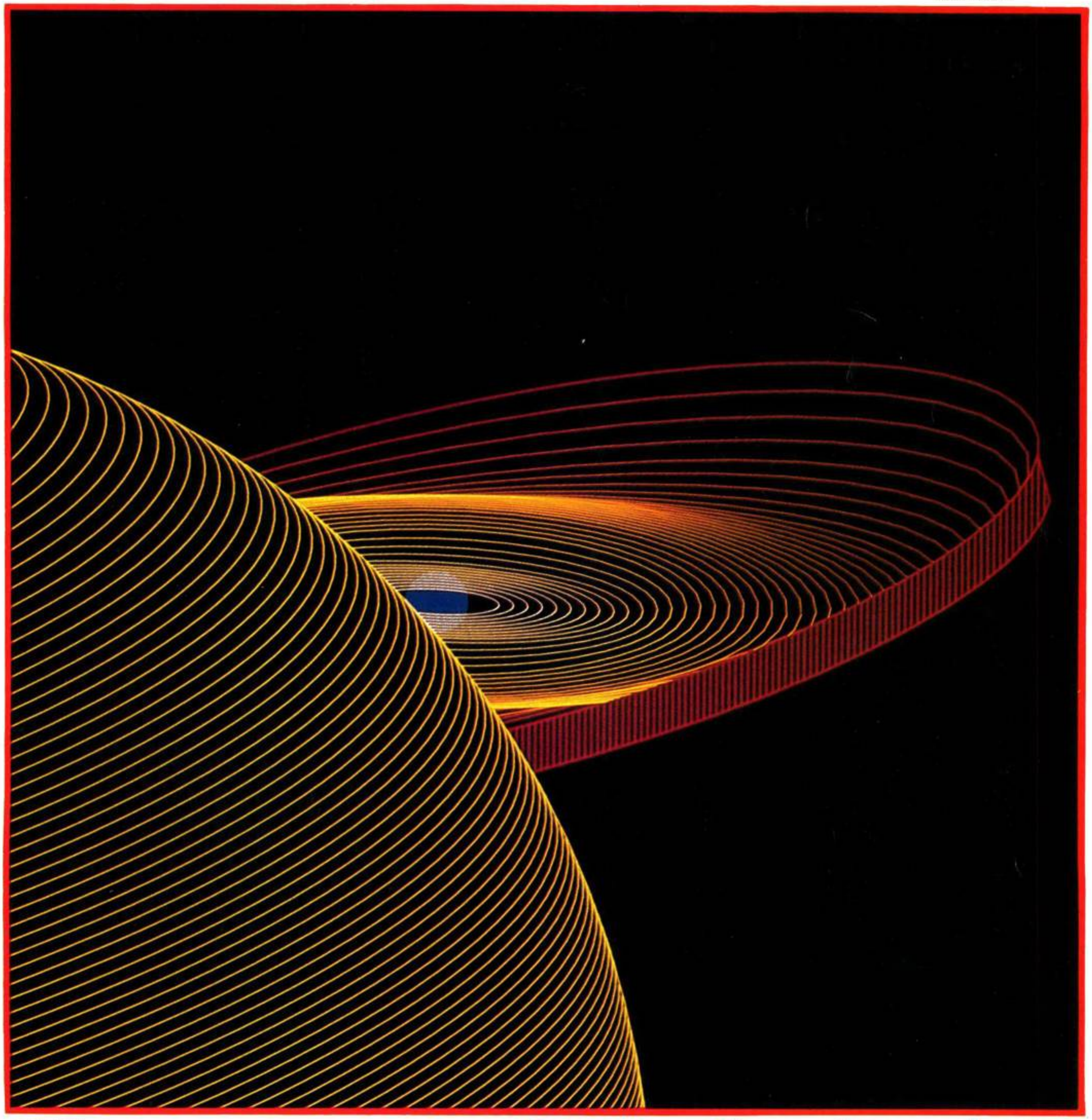
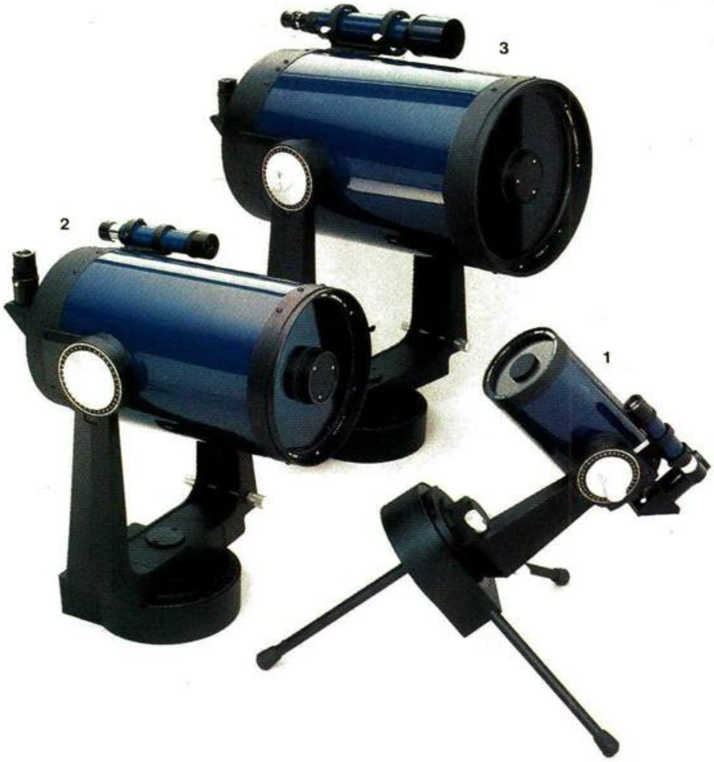
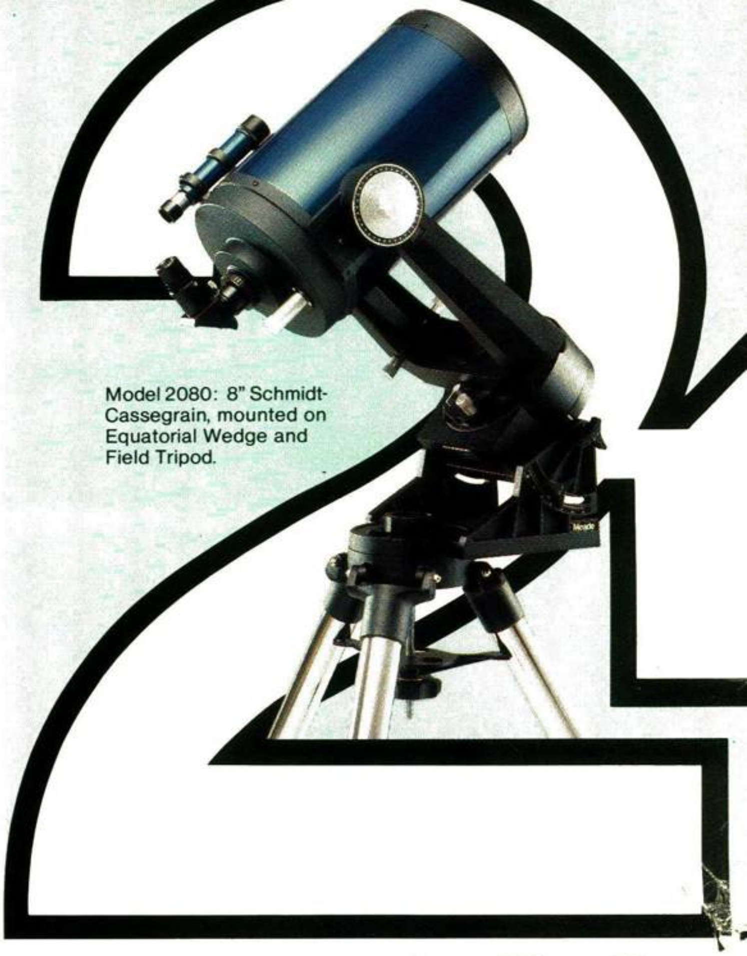


Computer View of Hercules X-1

Meade Schmidt-Cassegrain Telescopes: **(1)** 4" Model 2044, with standard-equipment table tripod; **(2)** 8" Model 2080; **(3)** 10" Model 2120.





Model 2080: 8" Schmidt-Cassegrain, mounted on Equatorial Wedge and Field Tripod.

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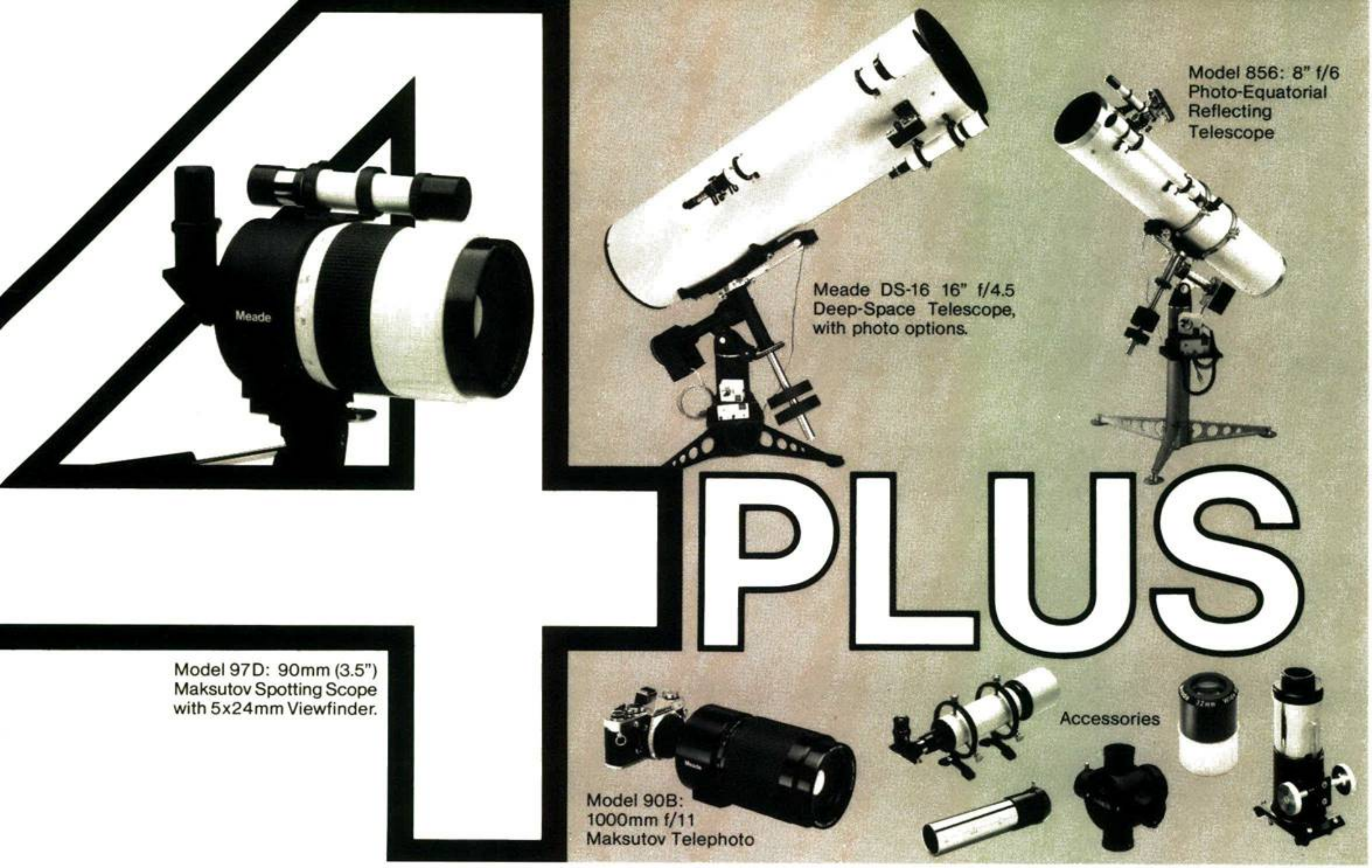

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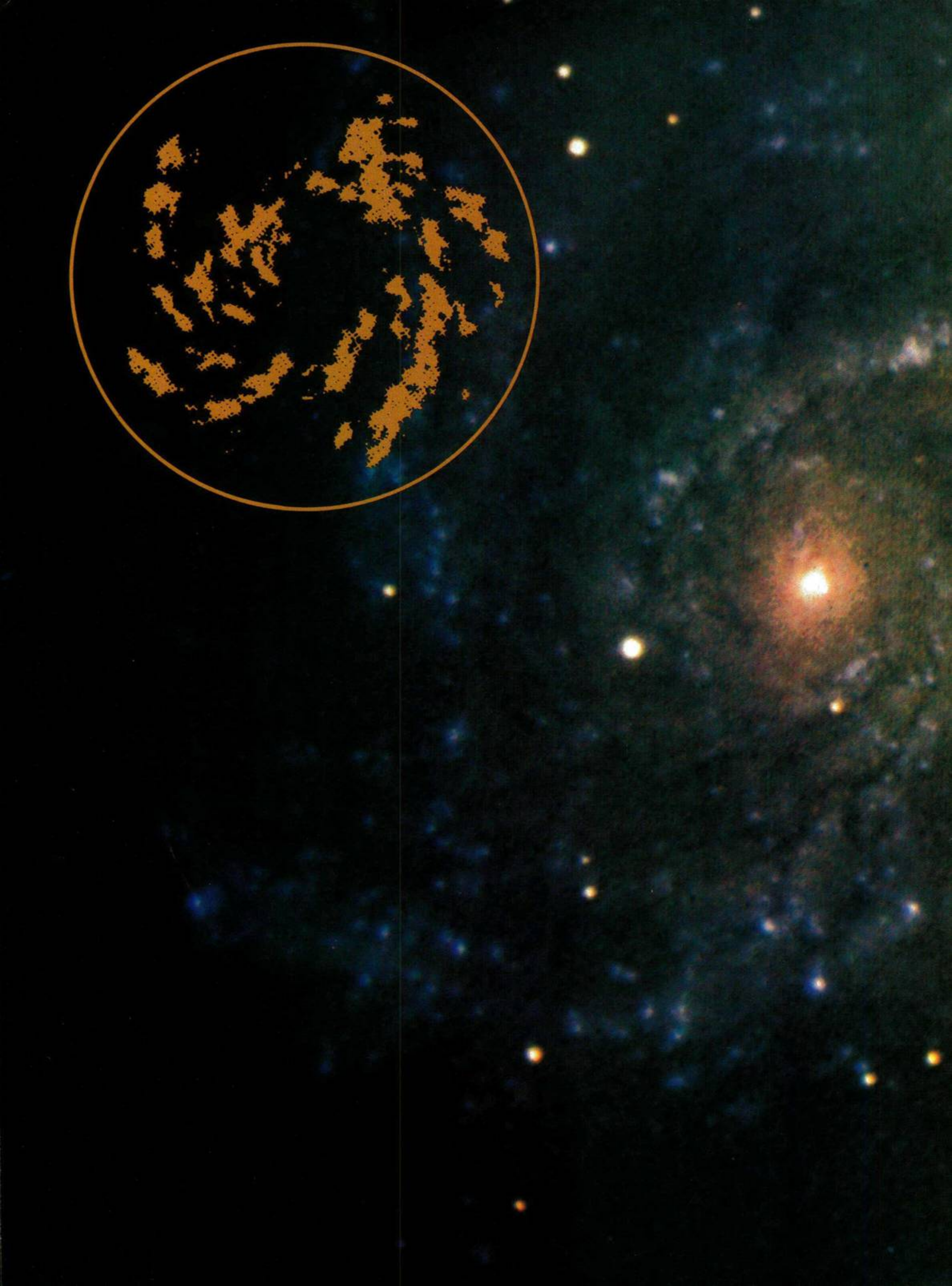

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Cover: Cloaked in a twisted, tilted disk of hot gas, a neutron star passes behind its giant stellar companion. This month, ASTRONOMY explores how astronomers use computers to simulate events too distant or too complex to see directly. The cover shows a computed model of Hercules X-1, an X-ray emitting star system over 16,000 light-years away. Photo by William Priedhorsky, Los Alamos National Laboratory. These pages: No one knows how spiral galaxies keep their unique shape, but a computer simulation of exploding stars (inset) shows structure similar to that of galaxy M-101 in Ursa Major. Photo by James Wray, McDonald Observatory; computer plot courtesy Philip Seiden, IBM.

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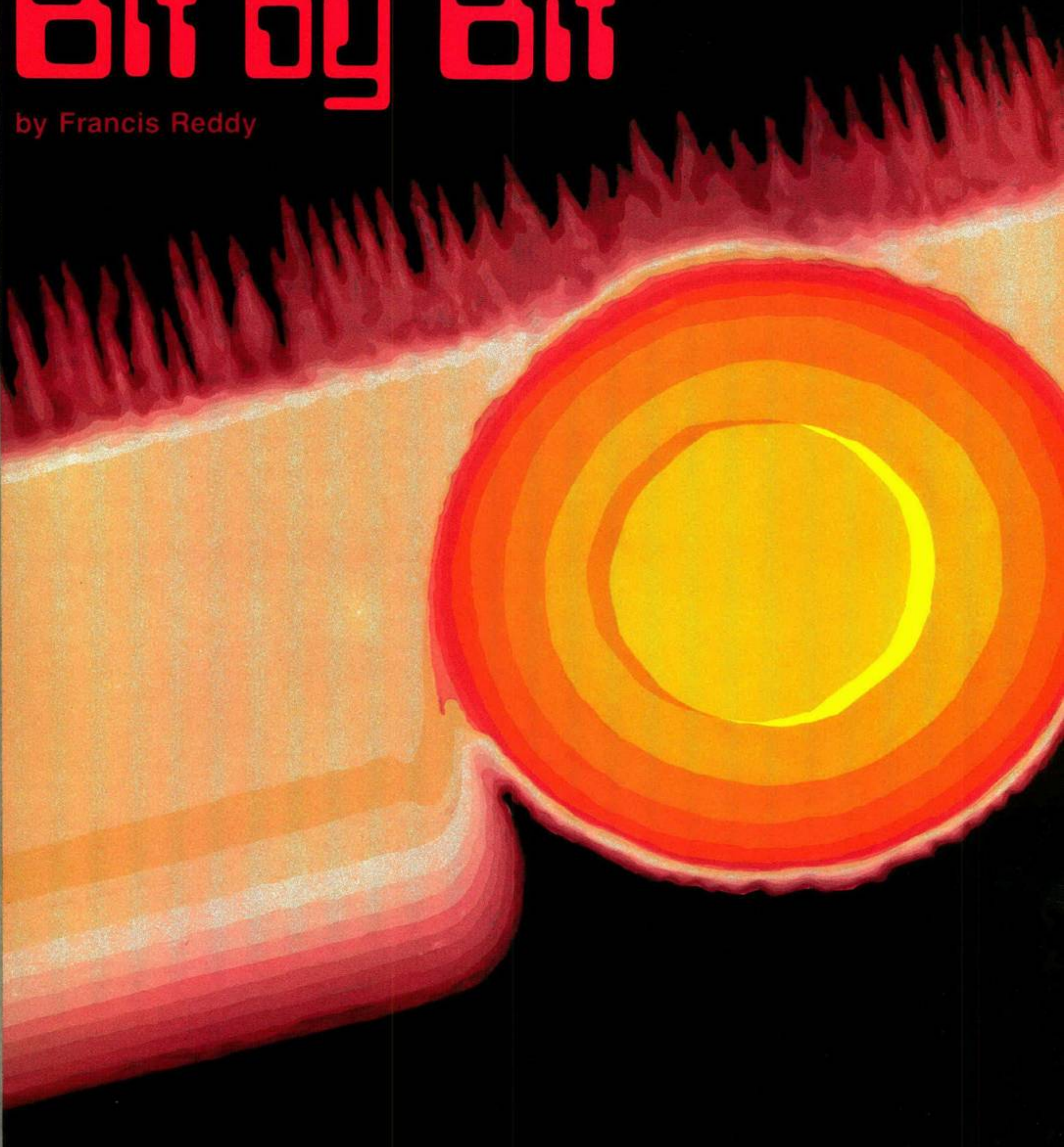
The Universe, Bit by Bit

by Francis Reddy



The availability of high-speed computers has sparked a revolution in science. By programming these machines with the rules governing the motions of atoms, researchers can get an atom's-eye view of a growing crystal. Using computer simulations of air flow, engineers can redesign an airplane or an automobile in a matter of days. Computer models of Earth's complex atmosphere let meteorologists predict weather trends weeks and even months in advance. In astronomy, as in these other fields, computer simulation holds great promise. By juggling unwieldy equations, the computer can make detailed models of objects human eyes may never see up close.

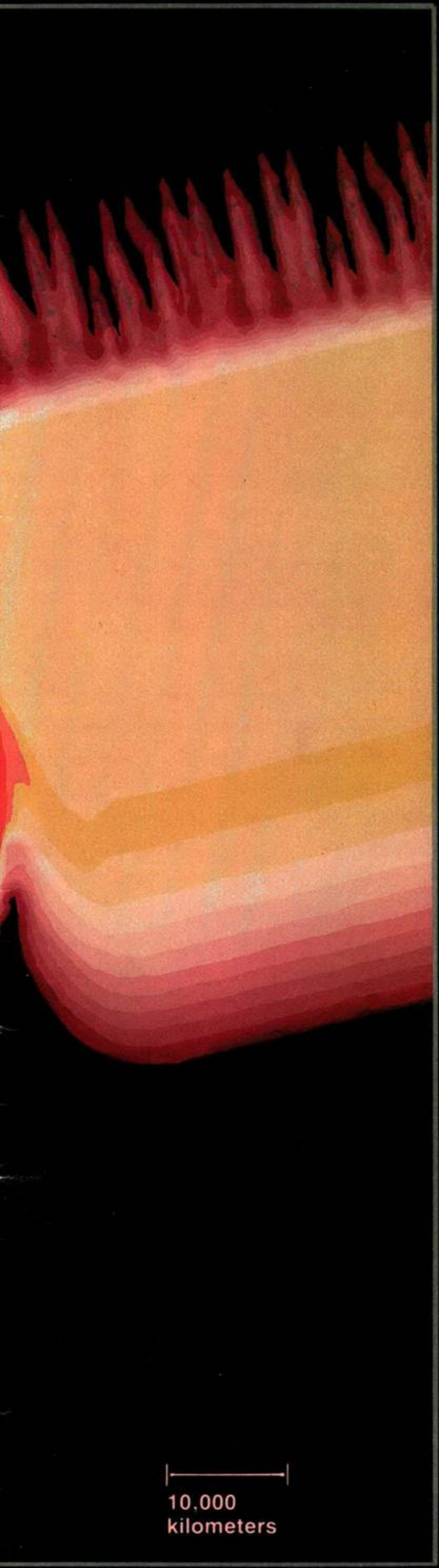
The explosion of a star is one of the most powerful and least understood events in the cosmos. An exploding star, or supernova, can release billions of times the annual energy output of our Sun and in the process throw off a shell of hot gas that expands into space at speeds exceeding 10,000 kilometers per second. Such titanic outbursts mark the transformation of a normal star into a small, dense object known as a neutron star.

Ronald Taam of Northwestern University and Bruce Fryxell of the University of Chicago were interested in binary systems where an X-ray emitting neutron star orbits a small normal star. In these systems, called low-mass X-ray binaries, the normal star may contain less than half the mass of our Sun and orbits its tiny partner in just a few hours. The neutron star buries itself in a flattened disk of gas stripped from its normal companion. The gas in this "accretion disk" heats up as it spirals toward the neutron star and gives off the X-rays we detect.

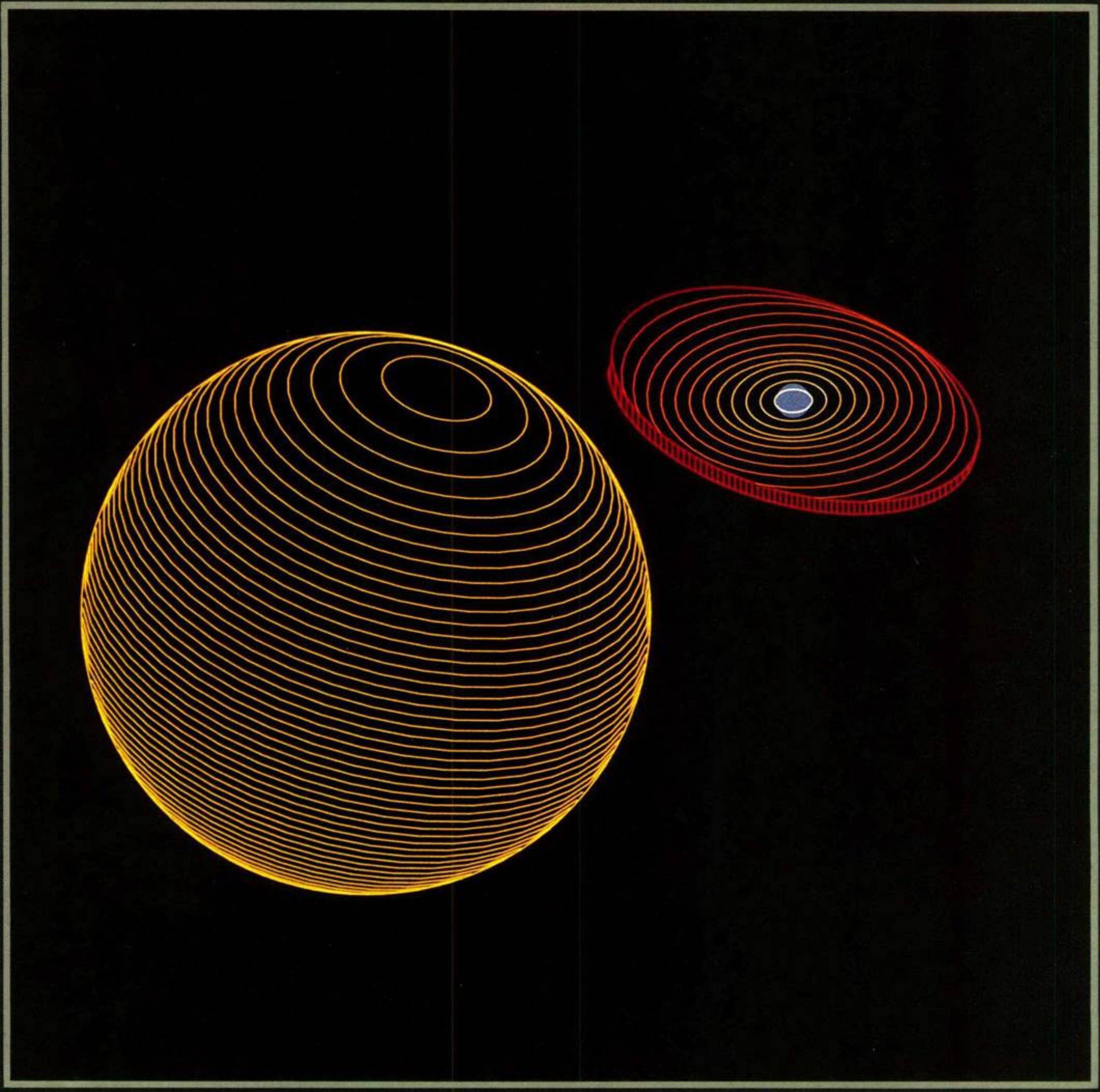
The presence of a neutron star in these systems bothered astronomers. How could a binary system survive if one of its components blew up? Most argued that the neutron star formed separately and later captured its stellar partner. But Taam and Fryxell wondered what would happen if a supernova *did* occur in a binary. "If the system lost a lot of mass," Taam notes, "the stars would become unbound." If the Sun suddenly ejected about half of its mass, for example, it could no longer hold Earth in orbit. "And if the binary system became unbound when the neutron star formed, it's clear that our idea wasn't a viable way of making low-mass X-ray binaries." The neutron star, they suggested, was originally a white dwarf star which exploded while stealing matter from its companion. Taam and Fryxell simulated the interaction between the supernova's shell and a small, reddish, M-type star.

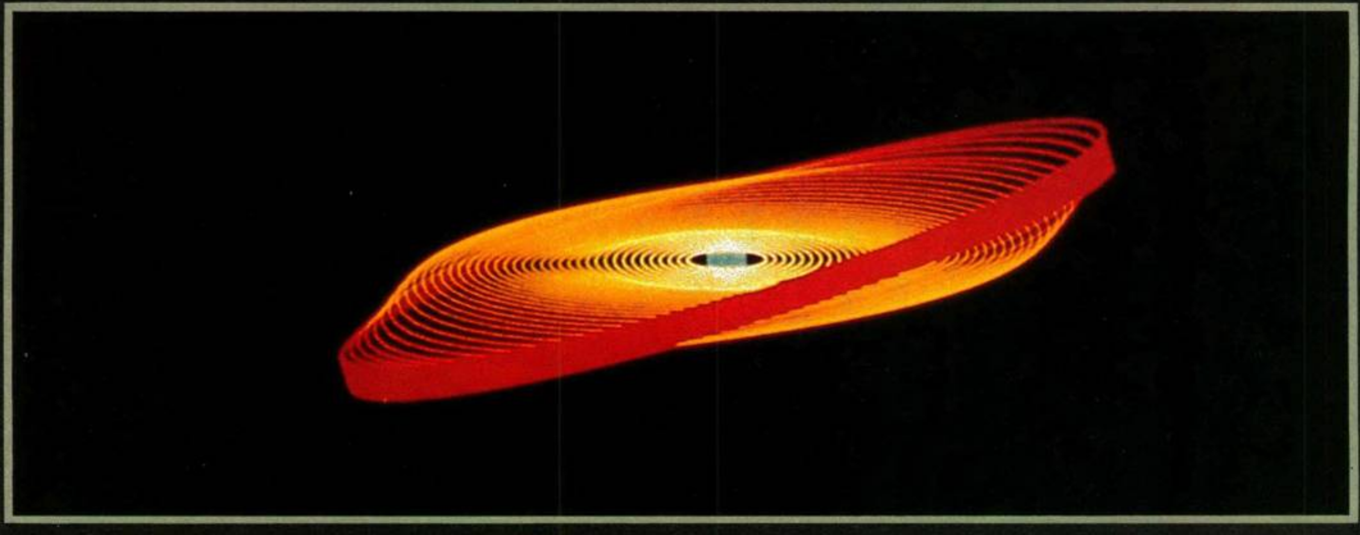
The results show that upon impact, the shell increases the temperature of the star's gaseous surface by millions of degrees. This hot gas streams off the star into the oncoming blast wave, and the resulting force "kicks" the M star away from the newly formed neutron star. Yet in every simulation, both the M star and the binary survived intact. "We were a bit surprised," Taam remarks. "The systems were very hard to disrupt. It's difficult to get rid of the companion." The explosion does, of course, disturb the binary. The M star loses mass and gets an outward push as the shell sweeps past it, and these changes modify the stellar orbits. "For hundreds of millions of years after the explosion," Taam says, "no gas flows between the two stars." The stars draw closer together as time passes and eventually resume mass transfer. Gas flows onto the neutron star and the binary becomes an X-ray source.

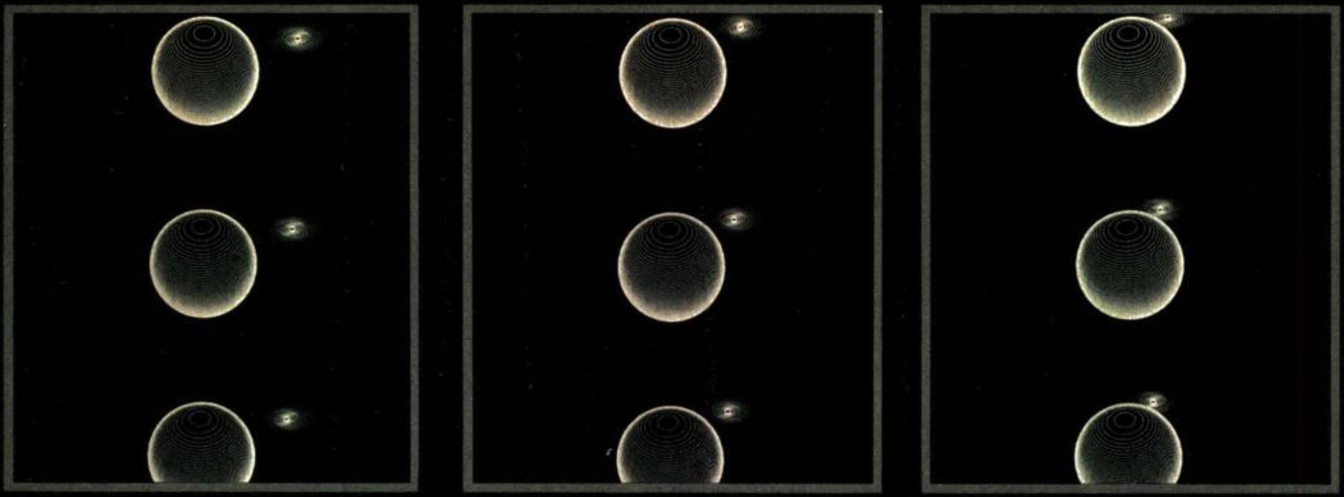
A low-mass M star of the type used in this simulation tightly holds even its outermost layers. But when a star uses up the hydrogen fuel in its core, its atmosphere balloons outward. The outer layers of such an evolved star — called a red giant — are very tenuous and only loosely bound. "The effect of a binary supernova on a red giant companion should be pretty interesting," says Bruce Fryxell. "I can't wait to try it."



Moving at five percent the speed of light, a supernova blast wave plows into a nearby star. Yellow and orange areas represent high-density gas; beige and magenta indicate low-density regions. Artwork is based on a simulation created by Ronald Taam and Bruce Fryxell.







A computer representation of the Hercules X-1 star system. A stream of matter (not shown) joins the giant star to the warped disk of gas that surrounds its tiny companion.

A computer lets us view the pair from a vantage point unobtainable from Earth — high above the plane where the stars orbit.

Wrapped in a twisted, tilted disk of stolen gas, a neutron star feeds on giant HZ Herculis. Gas falling onto the neutron star's surface heats up and emits high-energy X-rays.

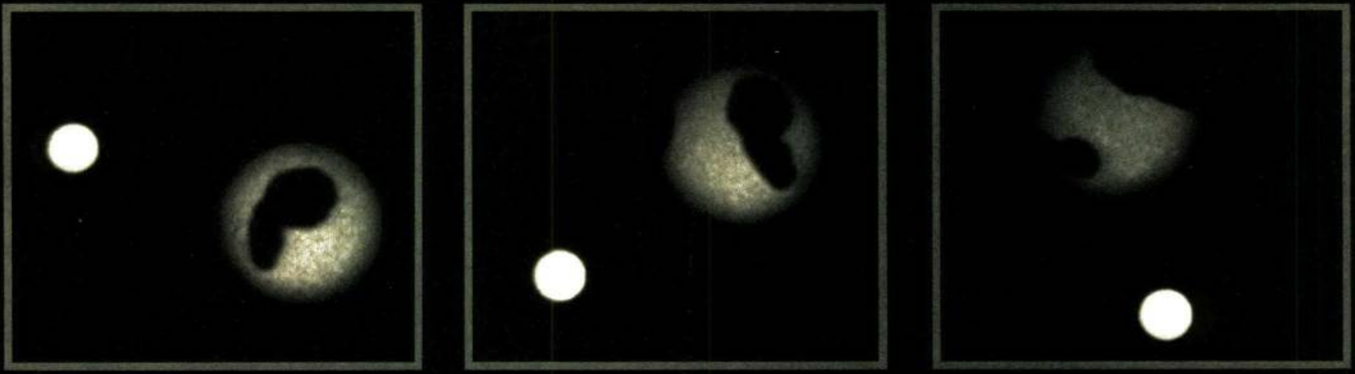
At Los Alamos National Laboratory in New Mexico, two astronomers used a computer to make the physics of one binary system easier to grasp. "Our simulation wasn't a graphic that gave us 'the answer,'" says William Priedhorsky, "but an aid in visualizing a complex physical model." Jacobus Patterson, an astrophysicist at New Mexico Tech, was Priedhorsky's collaborator on the project. "He had spent a lot of time working on the stability of stellar accretion disks," the Los Alamos researcher recalls, "and the most famous example of this sort of system is Hercules X-1."

Early surveys of cosmic X-rays turned up a very strong source in the constellation Hercules. The emission ceases every 1.7 days for about six hours which suggests the X-ray source passes behind another body. The high-energy radiation comes from a companion of the blue giant star HZ Herculis, which lies some 16,000 light-years from Earth. The X-rays arise from a 40-kilometer-wide neutron star locked in orbit around the blue giant. A dense accretion disk of hot gas stripped from the giant surrounds the neutron star. Splashing onto the neutron star's surface, this gas emits X-rays so intense that they sear the exposed side of the blue giant. As a result, HZ Herculis is actually brighter on one side than on the other.

The blue giant eclipses its neutron star companion every 1.7 days, thus blocking its radiation. "On top of that," notes Priedhorsky, "the neutron star seems to turn itself off for 25 days, then turn on for 10 days, and then turn off again." Astronomers know that the X-ray source isn't really turning off because the hot side of the blue giant stays just as hot. Actually, the system's big, tilted, accretion disk creates this odd behavior. When the disk's inclined edge moves into our line of sight, it too eclipses the neutron star. The result is a 35-day variation in X-rays superimposed on the 1.7-day period of the eclipses.

The debate among scientists concerns the origin of the tilt in the system's accretion disk. "It all boils down to this," says Priedhorsky. "Does the disk generate the tilt itself due to instabilities we don't understand, or is it something imposed on the disk from outside?" Patterson and Priedhorsky simulated the so-called slave-disk model in which the disk tilts due to outside forces. According to this model, the blue giant from which the neutron star steals gas doesn't rotate smoothly — it wobbles, or precesses. Material flowing to the accretion disk carries this precession with it, transferring the giant star's wobble to the edge of the disk.

"It's a complex thing to visualize," Priedhorsky says. "The first time we talked about it, Jacobus tried to draw it on a blackboard and had a pretty hard time just sketching it. We didn't make the film to sell a particular model; we made it so that one model could be easily visualized and discussed." It took 24 hours for the sequence to run on the big VAX computer at Los Alamos. "Given the right software," Priedhorsky adds, "you might be able to produce this in a week's running time on a personal computer at home."



Ever since Galileo's discovery of spots on the Sun, astronomers have wondered if other stars had similar features. Periodic changes in the brightness of some stars implies the presence of spots carried in and out of view by the star's rotation. In the last few years, astronomers have identified several types of stars with large cool regions — starspots — on their surfaces. While astronomers have obtained good estimates of the sizes and temperatures of starspots, they lack detailed information about their shapes, movements, and origins — information they need to compare these features to those on the Sun.

At Lick Observatory in California, Steven Vogt and Donald Penrod are working on a way to get this information. Called Doppler imaging, their method creates pictures of starspots from distortions in a star's spectrum. Each atom emits and absorbs light at characteristic wavelengths. Dark lines superimposed on a star's rainbow-like spectrum reveal wavelengths that have been absorbed. If the star rotates rapidly enough, these lines become smeared due to a speed-induced color-shift known as the Doppler effect. Light coming from the part of a star rotating toward us is slightly bluer than it would be if the star weren't spinning; light from the part of the star rotating away from us becomes slightly redder. Vogt and Penrod can create accurate pictures of spotted stars by comparing the smeared spectral lines they observe with those generated by a computer. "It's sort of like unscrambling an egg," Vogt says. "There are a lot of possible solutions, and we have to choose the best."

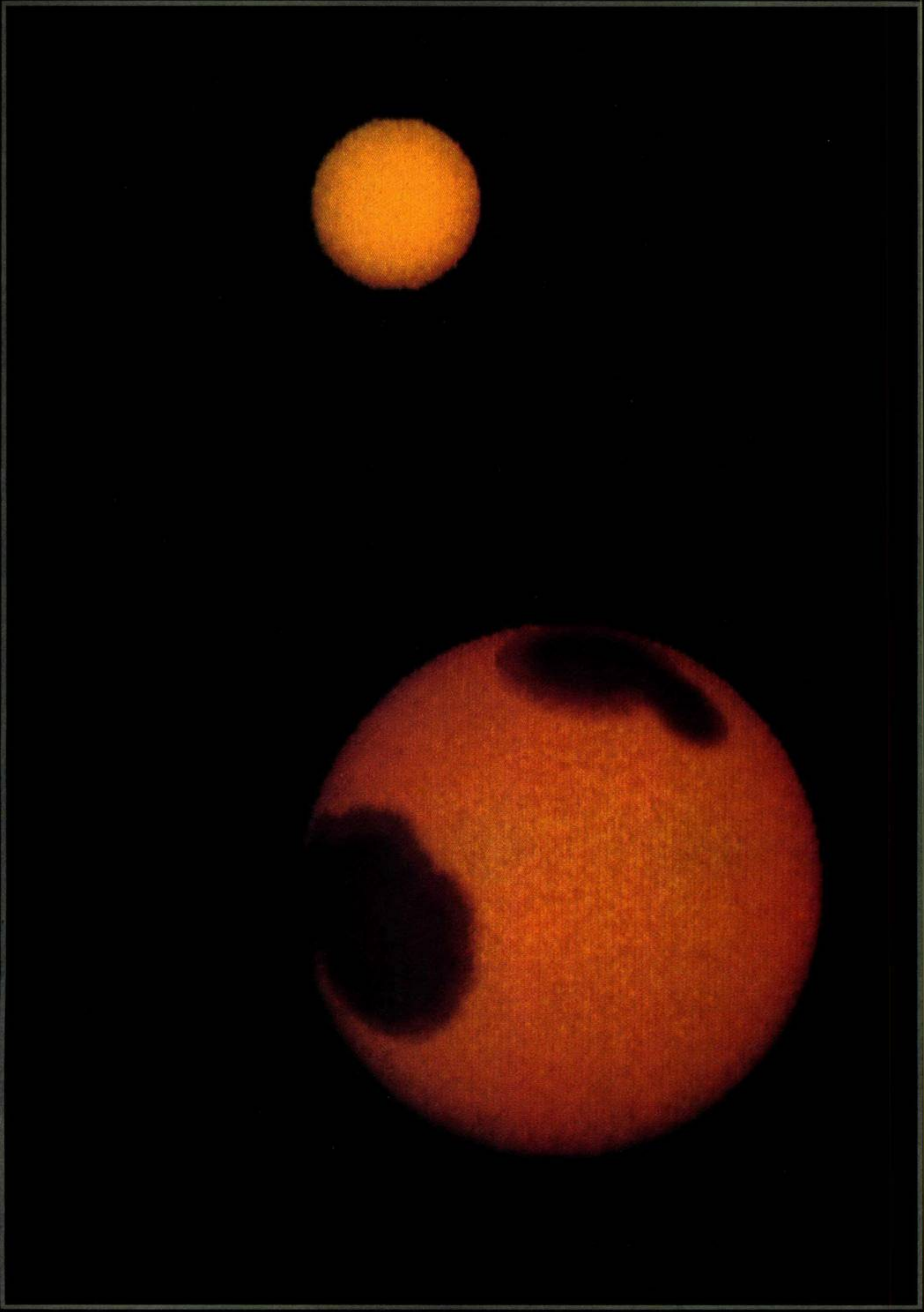
Vogt tried out his technique on HR 1099, a star system located about 116 light-years from Earth in the constellation Taurus. In this binary, a star very similar to our Sun circles a cool, bright, orange star well on its way to becoming a red giant. Locked in each other's gravitational embrace, the stars orbit one another every 2.8 days. No material flows between them — that phase will come later in the system's life — but the proximity of its companion keeps the orange subgiant spinning rapidly. The star rotates with a speed of 40 kilometers per second — 20 times faster than the Sun. This rapid rotation is a key ingredient in forming the starspots.

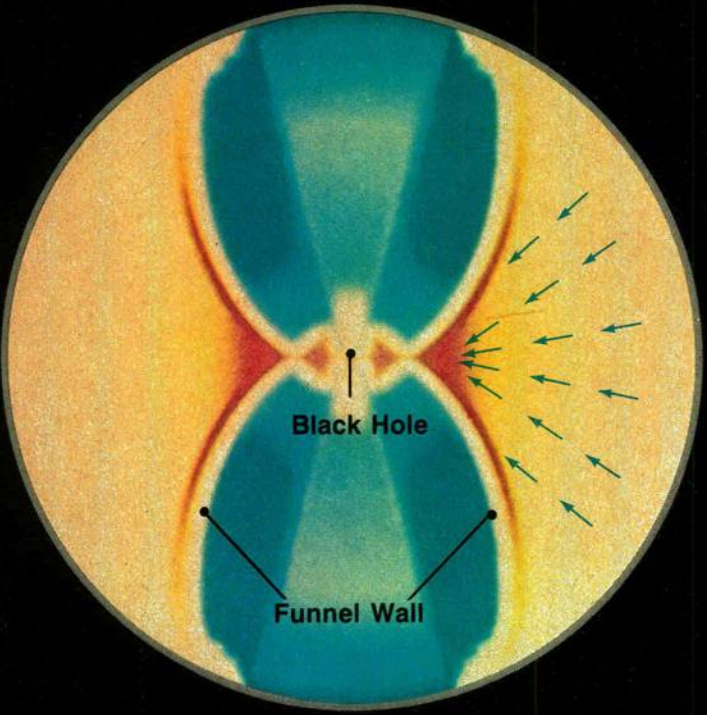
"From our observations," Vogt notes, "we know the star's rotation period, the orientation of its spin axis, the temperature of the undisturbed surface, and the temperature within the spots." Using a computer, Vogt creates a numerical star with just these characteristics. After looking over the star's spectrum, he estimates the positions of its starspots. "I actually have a globe on my desk and paste spots on it based on the spectral data," he says. "This gives a crude first approximation of the size and location of the spots, which we add to the numerical model." The computer then generates spectral lines that would appear if the model star were being observed. "We just compare the computed lines with those we actually see. If they don't match, then we move the spots around a bit and try again."

When the spectra of star and model match, the computer creates a realistic picture of HR 1099. "In terms of resolution, this is like being able to see Lincoln's ear on a penny 3,000 miles away," Vogt remarks. "Even under perfect conditions, you'd need a telescope half a mile in diameter to see these details — and it'll be a long time before we get one that big."

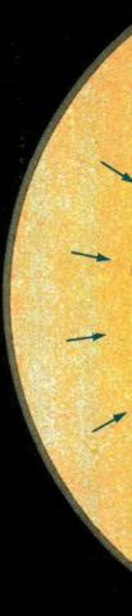
HR 1099's two giant starspots may be more similar to features observed in our Sun's corona than true sunspots; the magnetic fields emerging from a star's interior give rise to all these phenomena. HR 1099's internal structure and rapid rotation create magnetic fields hundreds of times more powerful than those on the Sun.

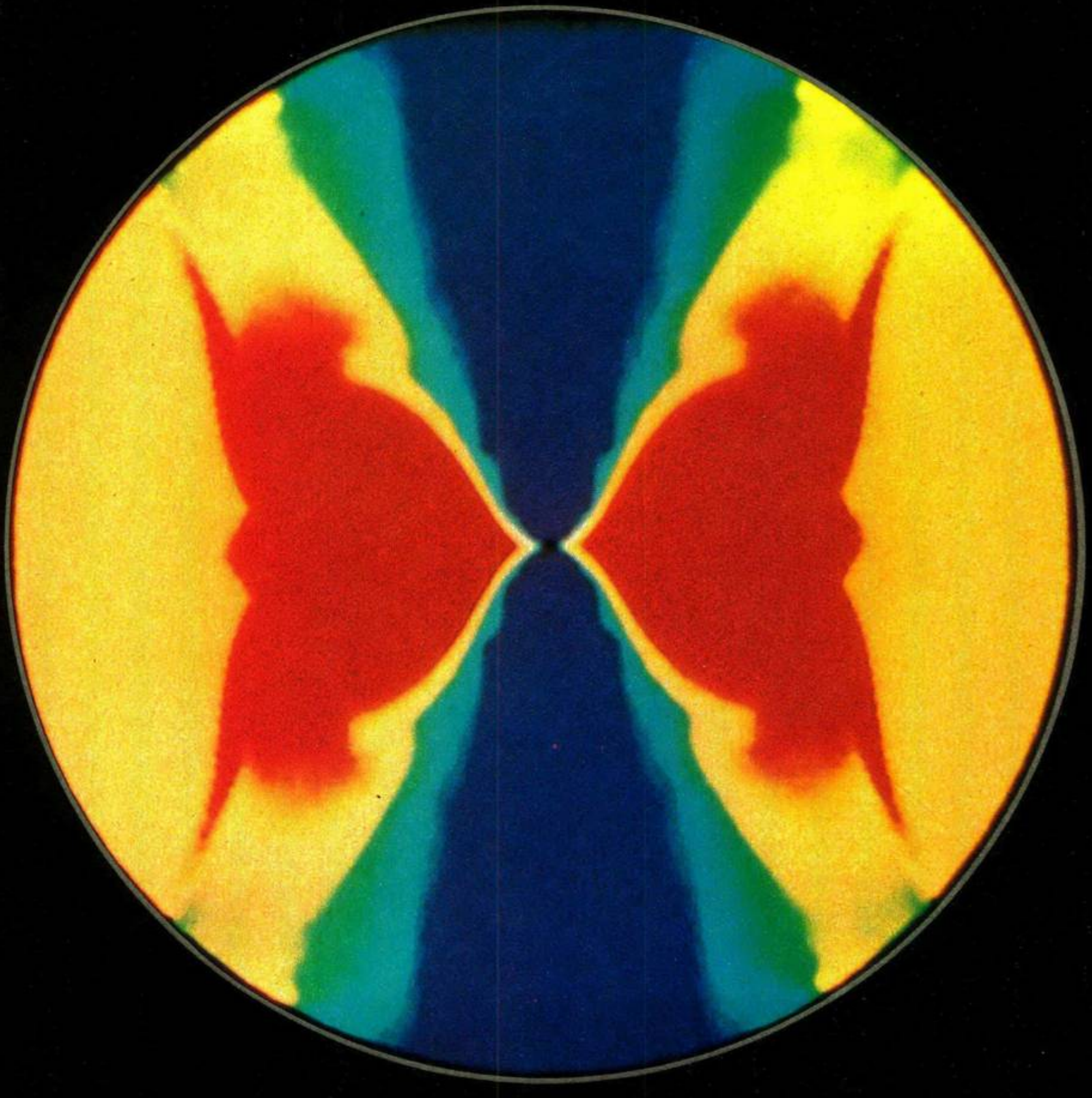
Resembling huge blemishes, dark starspots blanket the orange surface of HR 1099. Its yellow companion, which circles the star once every 2.8 days, is about the same size as our Sun.



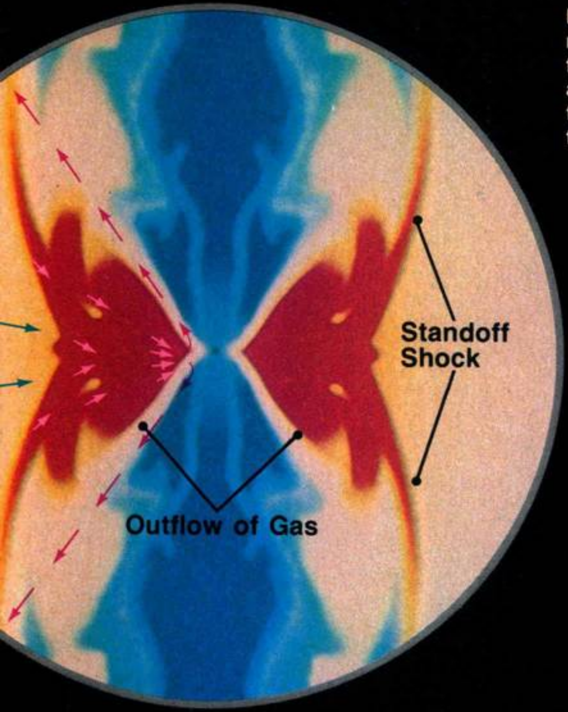


When the calculation begins, gas surrounding the black hole starts spiraling inward. The hole quickly gulps down the slow-moving gas above and below it, creating a funnel. Arrow length indicates gas velocity (short equals slow, long equals fast) and color suggests gas temperature (blue equals cool, red equals hot).





Moving faster and faster, the infalling gas eventually reaches a point where its rapid motion counteracts the black hole's gravity. This "centrifugal barrier" slows the inward fall of material. Faster-moving gas slams into the slowed gas, heats it up, and creates a hot, dense, "standoff shock" outside the funnel wall. Hot, dense gas leaking through the standoff shock reaches a rarefied area and expands. Some of this gas escapes up the sides of the funnel.



At the end of a computer simulation, a supermassive black hole (dot at center) sits in the midst of an even flow of infalling gas. This view is a cross-section of the gaseous sphere around the hole. Color indicates gas density, with red showing the highest density and blue representing vacuum. Hot gas flows out along the sides of the hourglass-shaped region — could this be the start of a cosmic jet extending millions of light-years into space?

Astronomical modeling isn't restricted to weird stars. Two astrophysicists from the University of Illinois, John Hawley and Larry Smarr, used a supercomputer to simulate the maelstrom at the core of a galaxy.

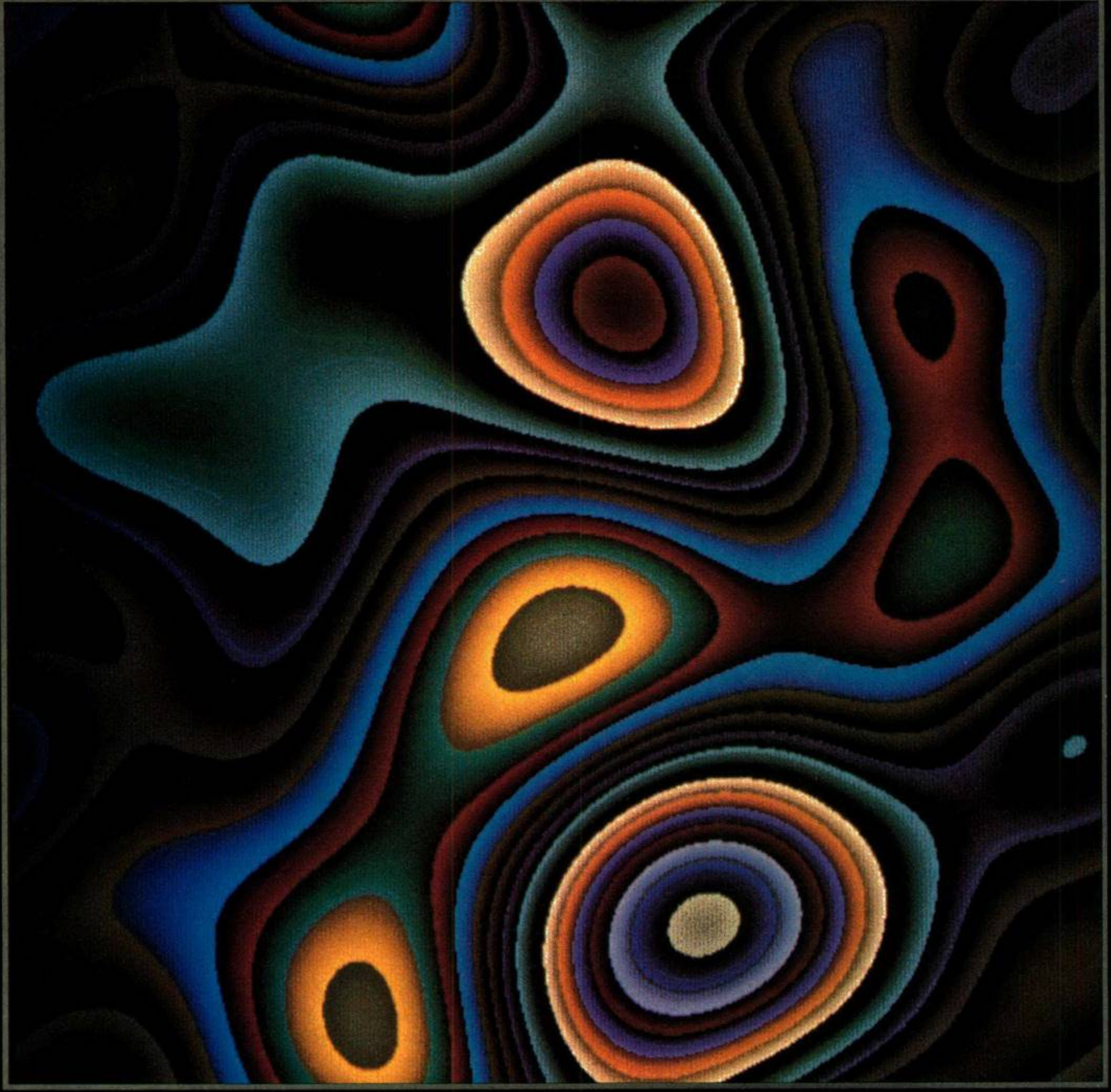
The intense activity found in quasars and in the cores of some galaxies has puzzled researchers for years. Most believe the fundamental power source of these objects is the gravitational energy released by gas falling into bizarre entities called black holes. A black hole is so compressed that one containing enough material to make a hundred million suns would be little larger than our solar system. A black hole's gravity is so great that even light cannot escape it — hence its name.

Hawley and Smarr ran a series of numerical experiments on a supercomputer at the Max Planck Institute for Physics in West Germany. They began with a hundred-million-solar-mass black hole in the center of a sphere of cool, non-rotating gas. When the calculation starts, all physical forces are turned on — the computer juggles equations dealing with hydrodynamics and general relativity, and calculates the condition of the gas throughout its numerical model. Even with the Institute's super-fast Cray-1, the simulation took several hours to run. Hawley describes the result as a "gargantuan amount of numerical output" that for the first time reveals the complex dynamic flow of matter near a giant black hole.

"Full-color images best represent the information contained in the solution," Hawley says. "They let you sort out the physics of the resulting flows easily." The researchers needed to turn the computer's vast list of numbers into individual pictures. But only a movie can illustrate how the flow changes with time — the astronomers actually needed a long sequence of color pictures. "Only a supercomputer can perform the amount of number-crunching required to produce these images in a short time," he adds.

"These experiments have revealed a number of new physical processes which occur in gas flows near black holes," says Hawley. Infalling material spiraling toward the hole moves faster and faster; the accretion disk flattens out. Eventually, the infalling gas reaches a point where its rapid motion creates a centrifugal force that counteracts the black hole's gravity. This "centrifugal barrier" is the most important aspect of black hole inflows uncovered by Hawley's computer runs — it acts as though it's a solid surface. Fast-moving gas rams into the material slowed by the barrier and heats it up. Working its way through the barrier, the hot gas expands as it nears the black hole. Some of this hot, rapidly-moving gas manages to shoot away from the hole.

Astronomers have discovered many galaxies that appear to be shooting jets of gas millions of light-years into space. Black holes are the preferred "engines" for these cosmic jets, but Hawley says a central astrophysical problem lies in converting the energy of infalling matter into gas and radiation that flows away from the hole. Through computer modeling, Hawley and Smarr revealed this hitherto unknown mechanism that squirts hot gas away from a black hole.



A snapshot of random density fluctuations before the small-scale perturbations were smoothed out.

Shortly after the Big Bang, small changes in the density of matter and energy occurred throughout the universe. In this computer-generated "snapshot" of these random fluctuations, all but the largest density perturbations have been smoothed out by the interaction of matter and radiation. Lime, yellow, and green areas mark relatively compressed regions; olive and turquoise mark increasingly rarefied regions.

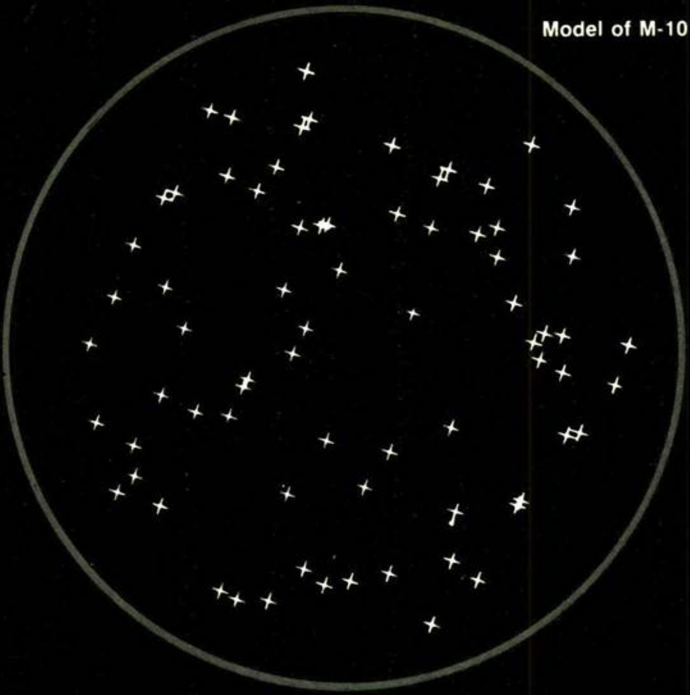
Some 18 billion years ago, all the matter in the universe began shooting outward from a tremendous explosion — an event scientists have nicknamed the "Big Bang." Cosmologists and astrophysicists base their versions of cosmic history on established physical relationships and astronomical observations of the present-day universe. Computers can take a cosmological theory, simulate the conditions it predicts, and actually follow the evolution of a small piece of the young universe. Such numerical simulations help point out the failings of a given theory.

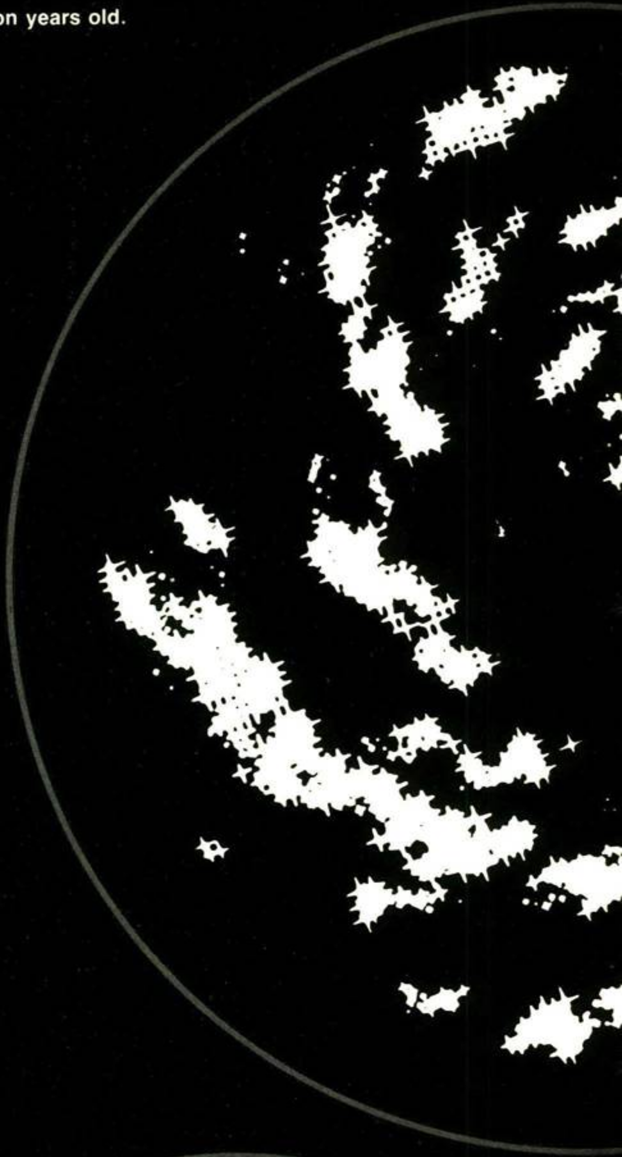
"According to our present understanding," says Stanislav Djorgovski of the University of California at Berkeley, "the galaxies and clusters of galaxies we now see have formed from density perturbations that shortly followed the Big Bang. That is, there were some regions denser than the average, which started collapsing under their own gravity and subsequently formed the present-day galaxies and clusters." Djorgovski ran computer simulations based on one current model of the early universe, the adiabatic or "pancake" theory proposed by Yakov Zel'dovich of the Institute of Applied Mathematics in Moscow, and Joseph Silk and Alexander Szalay of the University of California at Berkeley.

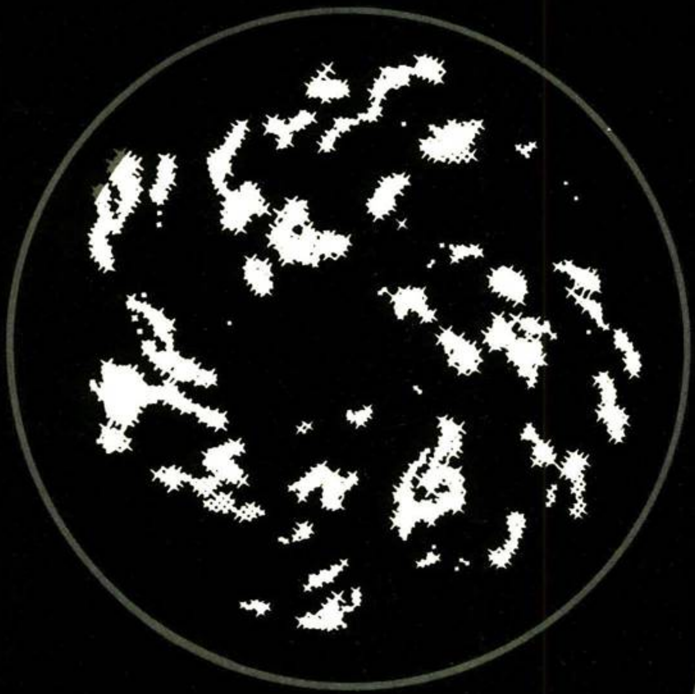
Early on, the universe consisted of a hot, dense, expanding gas. Some regions were a bit more dense than others, and these enhancements of density acted like ripples running through the cosmos. As the universe aged, all but the largest density fluctuations were smoothed out by the interaction of energetic radiation and colliding matter. According to the adiabatic theory, these giant perturbations collapsed into huge pancake shapes. At the edges of these great pancakes, strings of high-density material collapsed to form clusters of galaxies.

How did the perturbations originate? "We don't know," Djorgovski says, "but it is likely that their roots are somewhere in high-energy particle physics." One entity commonly invoked by cosmologists is the neutrino — a fast-moving, unsociable, subatomic particle. If neutrinos have a tiny mass, as recent experiments suggest, they would have been the first particles to cluster together. As neutrino clusters grew, their gravity initiated density enhancements in the universe and allowed larger structures — proto-galaxies — to form. One thing is clear about the pancake theory — it is far from complete. We know that galaxies are ancient structures that formed at least 10 billion years ago, but the galaxies predicted by the adiabatic theory aren't nearly this old.

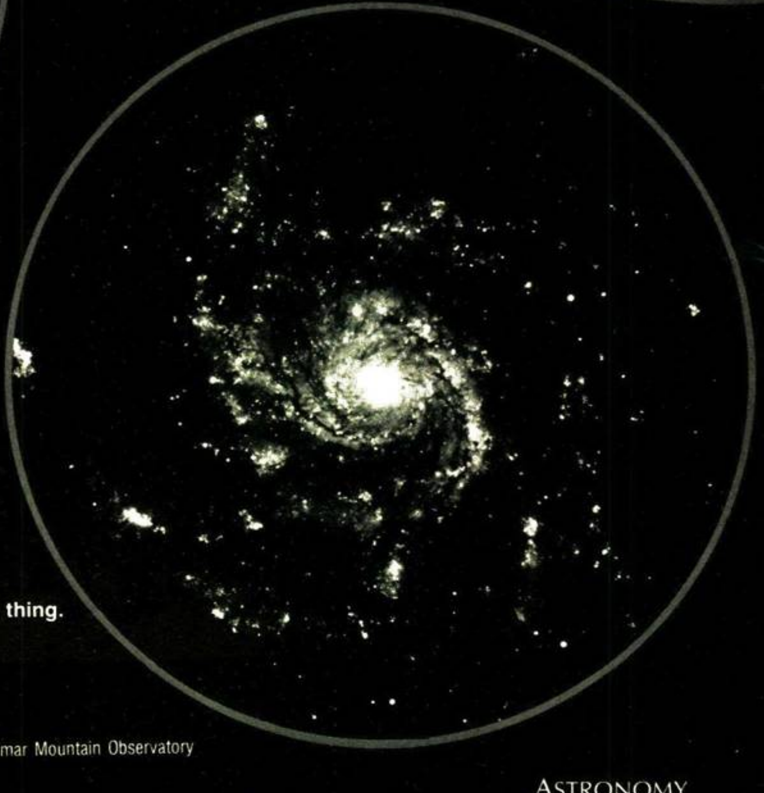
Model of M-101 four million years old.





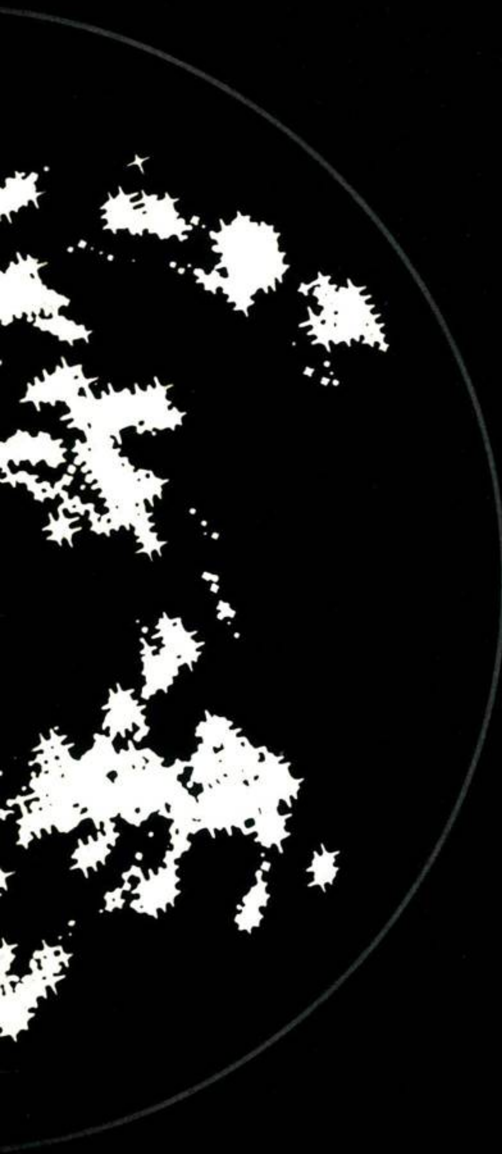


Model M-101 after 100 million years.



Spiral galaxy M-101 — the real thing.

Palomar Mountain Observatory



Model M-101 after 400 million years.

If a supernova's blast wave can initiate the formation of new stars, as recent evidence suggests, they may also generate a galaxy's spiral structure. Philip Seiden used the rotational velocity of galaxy M-101 in Ursa Major to create this model, which has evolved to an age of 400 million years. Clusters containing bright young stars are represented by large crosses; older, fainter star clusters are depicted by small crosses.

Computer models have also illuminated the complex interactions from which the structure of an individual galaxy arises. Our own pinwheel-shaped Milky Way Galaxy belongs to a class of systems that presents astronomers with a form seemingly impossible to maintain — the spiral. Just a few rotations should erase any spiral pattern, yet these galaxies are billions of years old. Although the Sun has spun around our Galaxy at least 20 times during its life, the distribution of the Milky Way's hot gas still forms a distinct spiral shape. Clearly, some mechanism works to maintain or regenerate a galaxy's spiral arms — but what can it be?

In the past few years, astronomers have found evidence that the blast waves of supernovae — the cataclysmic explosions of stars — can trigger the formation of new stars. Some fraction of the stars thus formed may themselves explode in later life and create another group of new stars in the process. A few of these stars may one day explode, so supernova-induced star formation can propagate through large regions of space in a fairly short time. Could this be the mechanism through which a galaxy's spiral structure is maintained? Philip Seiden and Humberto Gerola of IBM's Watson Research Center tried to answer this question by simulating the process on a computer.

Their model galaxy consisted of rotating concentric rings. Just as the inner parts of a galaxy rotate faster than its outer regions, the model's inner rings spun more rapidly than the outer rings. The rings were divided into boxes and each box was labeled to identify what was going on within it: those forming stars were labeled "star"; those initiating star formation in neighboring boxes were called "supernova." The computer determines the probability that a given box will become a supernova by the time the model galaxy completes another rotation. Previous models didn't include randomness — a key ingredient in nature — so Seiden and Gerola refer to their process as "stochastic self-propagating star formation."

In the computer model, star clusters formed from supernovae become stretched by the galaxy's rotation to form spiral-shaped appendages. These arms smooth out after a few turns, but new star clusters form before they disappear completely. As the galaxy's spin shears the new clusters, another arm forms. The galaxy exhibits a stable spiral pattern, even though individual features disappear. In addition, Gerola and Seiden discovered that when they used the actual rotation rate of a given galaxy, their model produced a pattern with the characteristics of that galaxy. On the basis of their results, they believe supernova-induced star formation to be an important mechanism for generating and maintaining galactic structure.

We've seen only the first revelations from the computing revolution in astronomy. Yet even now, as physicists attempt to simulate the circulation of Jupiter's turbulent atmosphere and cosmologists peek at the beginnings of the universe, researchers argue that the computing facilities now available at universities are insufficient. The Cray-1, which is manufactured by Cray Research, Inc. in Minneapolis, is one of the most common supercomputers, yet there are fewer than 100 of them worldwide. Time on these machines can cost up to $3,000 per hour; critics charge that most government funding for time on supercomputers goes to government facilities, leaving university centers out in the cold. In an attempt to remedy the situation, the National Science Foundation recently allocated over $7 million for grants so that scientists in a wide range of disciplines can use a supercomputer.

To create his black hole simulation, John Hawley needed a total of 75 hours on a Cray-1. As the technology advances, computer simulations are creating progressively more accurate models of reality. But the cost of glimpsing those realities — of performing experiments on a numerical cosmos — is reaching truly astronomical proportions. "The technology and manpower requirements for performing these calculations," Hawley says of his model black hole, "are approaching the requirements and dollar investments of observational astronomy."

The Observatories of Jai Singh

by Stephen Deitmer

Say the word "observatory" and most people envision the silvery bullet-dome on Palomar Mountain or the windswept complex atop Hawaii's lunar-like Mauna Kea. Observatory means remote-controlled telescopes sweeping the heavens with computer-driven adjustments. Observatory means satellites, like Einstein, IRAS, and the Voyagers, each gathering data at all wavelengths from above the Earth's atmosphere.

But observatories haven't always been so sophisticated. About 250 years ago, one man's notion of astronomical observation produced some remarkable non-telescopic observatories. His name was Jai Singh II and he lived in India from 1686 to 1743. During the early 18th century, this ambitious maharajah built five observatories in northern India with techniques and insights more advanced than ever seen by Eastern astronomers.

Two legends explain Singh's life-long dedication to astronomy. One story tells of a young woman Singh was courting who asked him why she couldn't touch the stars. Singh's inability to answer led him to devote his life to astronomical measurements. The other, and more likely, story tells how the Mogul emperor of the time had to embark on an important journey at a horoscopically auspicious moment, yet the available zodiacal tables were ambiguous. Singh, displeased that he could not provide his lord with more accurate information, entered into astronomical pursuits.

For whatever reason, Singh — a contemporary of Newton — began his work armed with a thorough knowledge of astronomical literature. His library included the latest Hindu treatises on mathematics. Singh also read Ptolemy's *Syntaxis* (better known in the West as the *Almagest*), Flamsteed's *Historia Coelestis Britannica*, Newton's *Principia*, de la Hire's *Tabulae Astronomicae*, Euclid's *Elements*, and Mirza Ulugh Beg's astronomical tables.

To translate this book knowledge into more accurate measurements of heavenly bodies, Singh built five open-air observatories. Each of these he called a *jantar mantar*, which in Hindi means "computing device." His observatories still stand today in Delhi, Varanasi (Benares), Ujjain, Mathura, and Jaipur.

A train ride out of the old Delhi station about five hours south and west brings you to a city tucked into the rocky hills on the northern border of Rajastan's Thar Desert. There, beneath the spines of the mountains, the city of Jaipur displays the best-preserved and largest of Jai Singh's *jantar mantars*. In fact, Jai Singh's efforts contributed so much to the growth of this city — politically, administratively, and astronomically — that it took his name: Jaipur means "city of Jai." But it is his *jantar mantar* more than his name, which is his greatest legacy to the city.

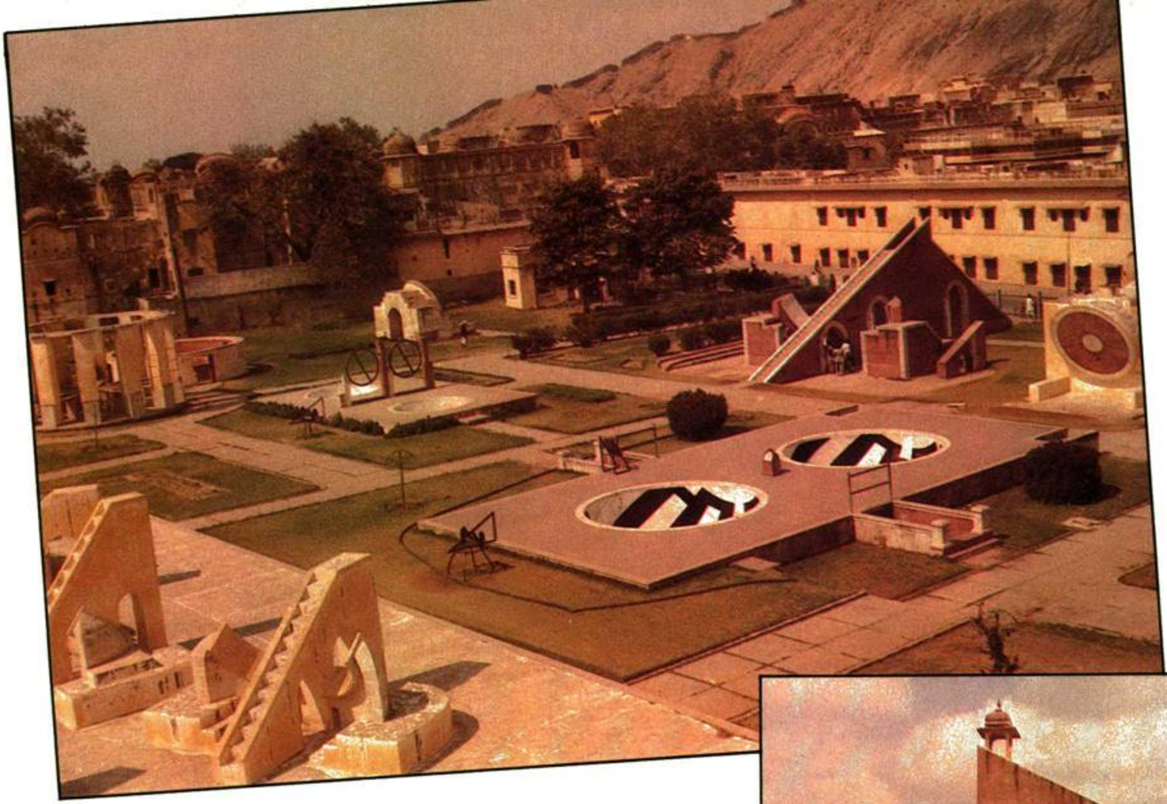
Across from his palace near the center of the old quarter, Singh's observatory draws busloads of tourists, whose first reaction is usually a combination of disbelief and awe. I thought I was in some god's backyard, with giant odd-shaped geometric playthings strewn haphazardly across the lawn. But what appear to be randomly-tossed things — sunken bowls, cut-away cylinders, huge triangles, twisting arcs — are actually precision astronomical instruments.

The most riveting of all is the gigantic Samrat Yantra, or "prince of sundials," which soars from the southeast corner of the grounds. Aligned with the meridian, this sundial's stair-stepped gnomon rises 90 feet and inclines at 26° 55′ — equal to Jaipur's latitude. At the peak of the long staircase is a belvedere — in classical architecture, a building that commands a good view. To this day, Brahman pandits make a midsummer's climb to this perch in the belief that from there they can predict the coming year's weather. Sweeping upward to the east and west of the gnomon's base are two gracefully twisting quadrants — quarter circles — on which the gnomon's shadow falls. The surface of each quadrant is white marble inscribed with scales for telling time. If the gnomon looks like an elephant's trunk bellowing at Polaris, the quadrants are his mighty ivory tusks.

The giant sundial measures apparent solar time as the gnomon's shadow crawls down the hour scale of the western quadrant and back up its eastern twin. Although this magnificent instrument was built so large that its quadrant scales can read to seconds of time, in reality the shadow of the gnomon has too fuzzy an edge for that much precision. (In addition, the east and west scales disagree by about two minutes.)

The two 50-foot-radius quadrants lie in the plane of the celestial equator, each centered on the gnomon's appropriate edge. Besides telling time, the Samrat Yantra can also give the declination of the Sun or any other celestial object. The marble face of each quadrant is several feet wide and has two scales engraved upon it, one along its upper (northern) edge and one on the lower, southern edge. To determine declination, you use the northern scale when an object is south of the celestial equator — for the Sun, this is between the September (autumnal) and March (vernal) equinoxes — and the southern scale otherwise.

Let's imagine it's 10 a.m. on a day in October and you, as one of Jai Singh's astronomers, wish to make an observation of the Sun's declination. You climb part-way up the gnomon and direct your assistant on the ground below to where he can observe the western quadrant's upper scale. You carry a staff in your hands. Stooping down, you extend the end of the staff a short way out over the edge of the gnomon. Peering over the edge yourself, you notice that the shadow of the staff falls on the ground



Left: Northwest from the Samrat Yantra in Jaipur lie the Rasivalaya Yantras, the bowl-like Jai Prakash Yantras, the smaller Samrat Yantra, the Narivalaya Yantra, and (at far left) the Ram Yantras. All photos by the author except those noted. Below: The 90-foot Samrat Yantra capped by its belvedere.

to the north of the quadrant's upper scale. Your assistant confirms this. You move down a couple of steps and try again. This time it looks like you're on the scale, but the assistant says you're a little too far south. You adjust slightly and he signals that everything's on target.

Now you look at where the staff lies on the edge of the gnomon. Along the edge where you're kneeling are two, separate, graduated measures. One measure belongs to the north quadrant scale, the other to the southern; you're careful to use the northern quadrant's measure. Reading the numbers tells you that today the Sun's declination is 6° 37′ south of the celestial equator. You note the number and descend to record it. (Had it been nighttime and the object a planet, you would have stretched a string between yourself and your assistant, while you moved up and down the gnomon until your helper told you the string pointed directly at the star.)

To confirm measurements and allow students and other astronomers to work while the Samrat Yantra was in use, Singh ordered the building of a similar but smaller equatorial sundial called the Laghu Samrat Yantra. Built of red sandstone and white marble, this instrument stands about six feet high. It can also be used to determine the declination of the Sun or a nighttime object.

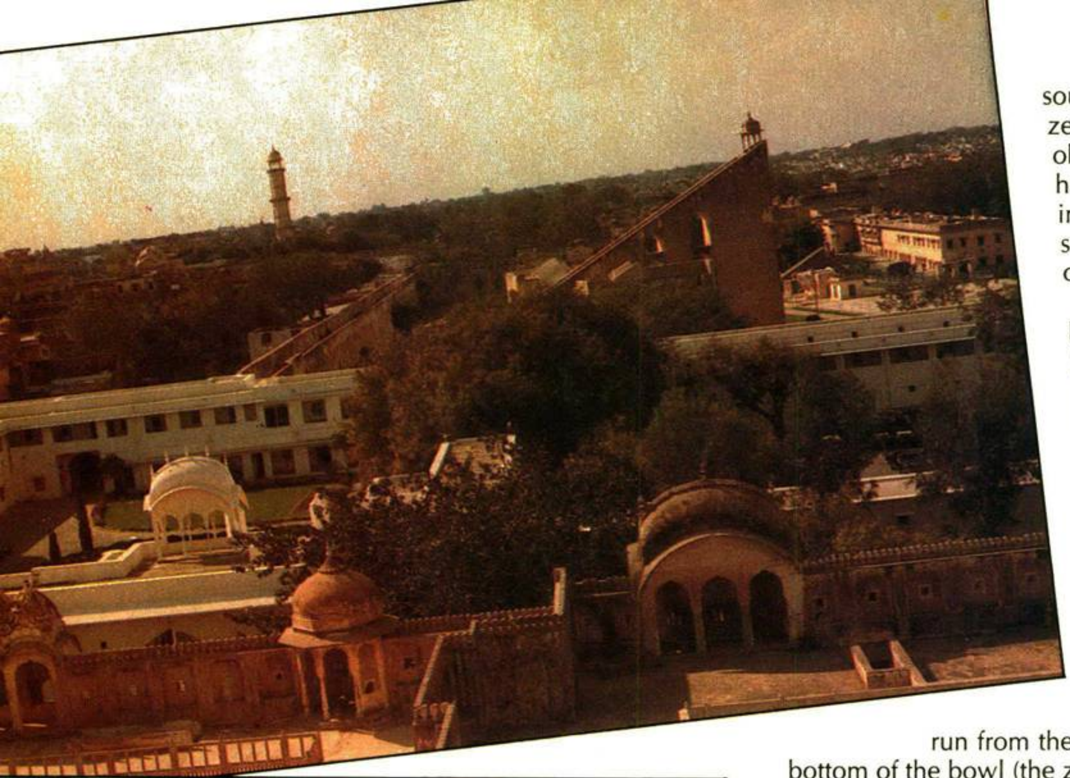
A third, smaller gnomon was built to sight the pole star, but this instrument, the Dhruva-Darshak Yantra, lacks scales and fulfills no other function.

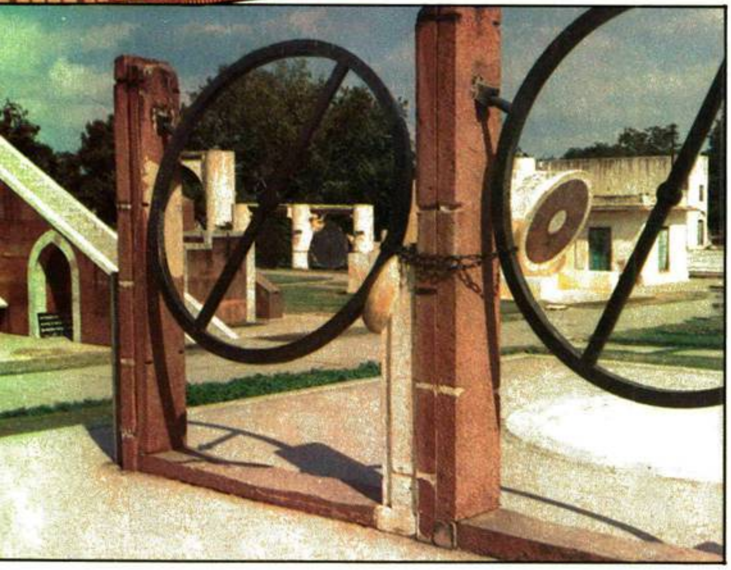
Set on a slightly raised platform to the west of the Samrat Yantra at the southern edge of the observatory are 12 sundial-like instruments. Each of these points in a slightly different direction, slopes at a slightly different angle, and rises to a slightly different height. And the pair of quadrants that accompanies each dial curls with a slightly different twist. At first, these instruments look like trial-runs that didn't come out quite right and were discarded in back of the observatory!

But these 12 devices are not failures — their idiosyncracies are intentional. Each of these Rasivalaya Yantras ("ecliptic instruments") belongs to one of the 12 divisions of the zodiac. Since the instruments use the ecliptic and not the Earth's equator for alignment, they must point in different directions.

The big sundials always aim north-south to match the Earth's rotation axis. However, because our planet's polar axis tilts 23° 27′ with respect to its orbit around the Sun (the ecliptic), the ecliptic pole is displaced relative to the rotation pole. This means that the direction toward the ecliptic pole constantly varies. Each of the Rasivalaya Yantras is aligned with one particular part of the ecliptic and may be used about two hours daily, when its corresponding zodiacal sign crosses the instrument's meridian. Using these instruments, Jai Singh's astronomers were able to observe the motion of the Sun, Moon, and planets in ecliptic coordinates.

Other types of sundials also adorn the grounds. The Narivalaya Yantra — a cylindrical dial — has two half-spheres, each set in the plane of the celestial equator. The north-facing dial reads time between the vernal and autumnal equinoxes, and the southern dial is used during the rest of the year. Astronomers knew the equinox had arrived when the Sun shifted from one side of the dial to the other. The two half-spheres are about four feet in





Top: The Jaipur skyline is broken by the Samrat Yantra's gnomon. Photo by Gauri Bhatia. Above: Between the Kapali Yantras are the two Chakra Yantras, equatorial sighting instruments. At left is the smaller Samrat Yantra, in the center background are the two metal astrolabes, and to the right is the south-facing dial of the Narivalaya Yantra.

diameter and project like Siamese twins from six-foot-high stands. Atop this odd-shaped instrument sits a traditional horizontal sundial.

In the northeast corner of Singh's open-air laboratory, is a huge masonry wall, called the Dakṣhinovritti Bhitti Yantra, with a 180° scale inlaid on its western side. At local noon, the Sun casts a shadow from an iron peg high on the wall and the scale measures the Sun's angular distance from the zenith. At night an observer runs a thread from the peg and sights his object. Staircases that go up and down the semicircular scale make sighting and reading the scale easier.

The eastern wall displays two 90° arcs with engraved lead scales marked to tenths of a degree; one arc faces south for objects south of the zenith, the other faces north for objects north of it. Both scales have their own iron pegs and intersect near the ground. The scales show the zenith distance of celestial objects.

To the northwest of the 12 Rasivalaya Yantras is a raised platform. Climb up on it and at your feet you see two marble hemispheres placed on an east/west line and sunk into the masonry. These armillary spheres — Kapali Yantras — are nearly identical. Each is an inverted celestial map. The rims of the bowls where you are standing represent the horizon, while in the marble concavity lines cross this way and that. Altitude scales run from the rim (the horizon) down to the bottom of the bowl (the zenith). Meridian parallels flank the prominently etched local meridian. The celestial equator, with its 12 horoscopic divisions, is also marked.

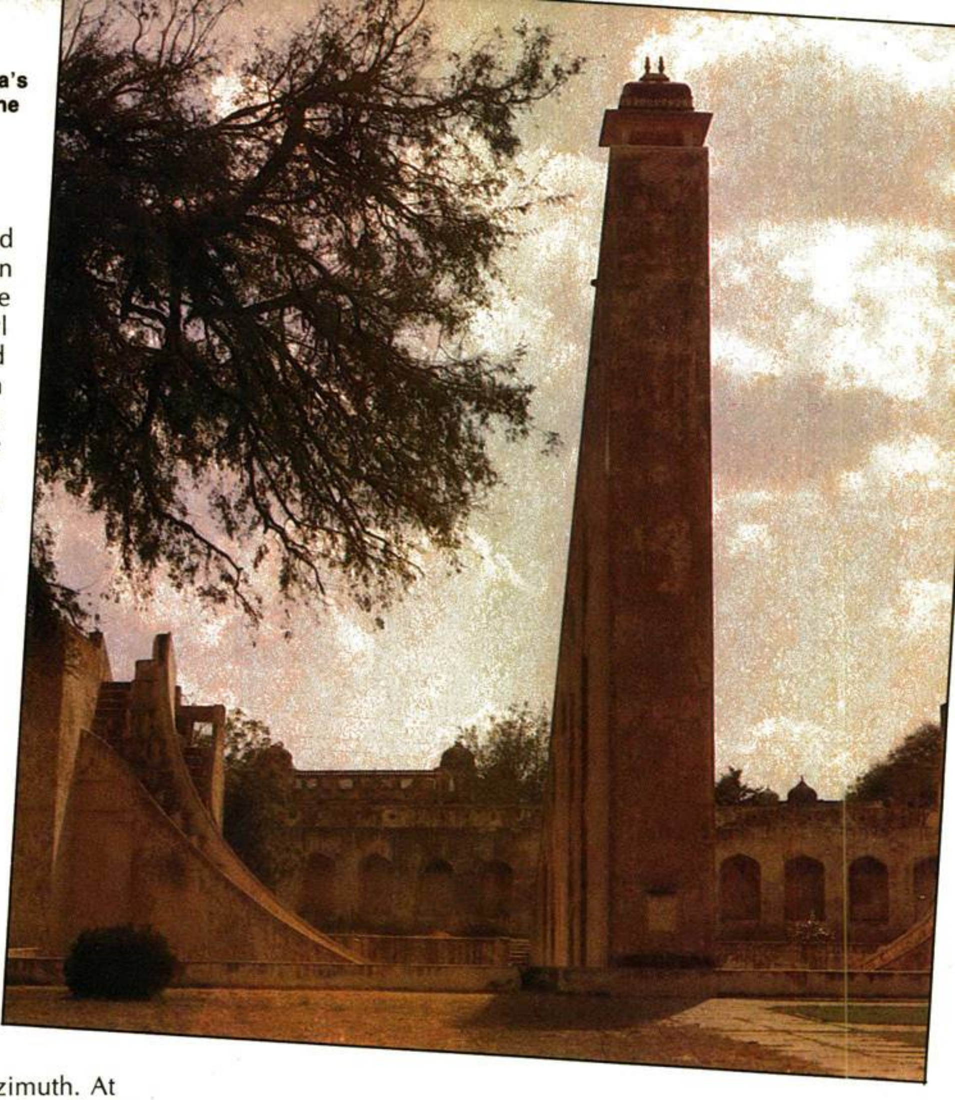
Singh used the eastern bowl strictly as a map to help him find his way around the sky. But the western Kapali Yantra was used as a measuring device. Two wires ran east-west and north-south across the top of the bowl, supporting a metal ring where they intersected, directly over the bowl's zenith point. When sunlight casts a shadow of the ring onto the marble you can read the Sun's position from the bowl's inscribed scales.

For nighttime observations, you actually step into the bowl and position yourself so you can see the object of interest through the suspended ring. It's necessary to get your eye as close as possible to the gradations on the bowl's surface, because your eye's position on the celestial map gives the position of the object. Singh apparently found working inside the bowl quite awkward — and it's easy to see why. Imagine having to scrunch yourself into odd postures in an inverted hemisphere while trying to hold steady on marble made slippery by dew! So the determined Singh reworked the armillary bowl and developed what came to be called Jai Prakash Yantras — "instruments of Jai's light."

The Jai Yantras lie in a north-south line to the east of the Kapali Yantras. They are also a pair of marble hemispheres sunken into a masonry platform, each about 18 feet in diameter. But to allow the observer more freedom of movement, Singh had sections of the bowls removed. This created narrow aisles which allow the observer to move in comfort. With the bowl's lowest point coming to about waist level, the observer can walk on the horizontal floor of the platform rather than struggle on the slippery slope of the bowl. Steps built under the bowl's rim let the observer position himself easily and hold steady for accurately sighting an object low on the horizon.

The cut-away aisles alternate with slablike sections of marble. The slabs and aisles radiate from the celestial pole, each being one hour (15°) wide. However, removal of the marble to create passageways also removed half the celestial map. But Jai Singh wanted these instruments

The staircase rising to the left of the Samrat Yantra's gnomon allows observers to read the scales on the massive eastern quadrant.



usable at all times, so he used complementarity. Where one bowl has an aisle, the other retains the graduated marble slab and vice-versa. If you could lift one bowl and place it inside the other, the two would fit exactly, forming one completely filled-in hemisphere. As a result, the entire sky can be surveyed at any time by using the appropriate bowl.

Standing somewhat apart at the western end of the observatory's grounds is an azimuth instrument called the Digamsha Yantra. Seen from a short distance, it appears to be nothing more than a circular wall, six feet high and about 25 feet in diameter. Inside the wall and concentric with it is a smaller circular wall, about three feet high and 15 feet in diameter. A cylinder three feet tall marks the center of the two walls. The marble rims of the walls are marked-off in degrees and tenths. Like the bowl-shaped Yantras, the Digamsha Yantra has a ring suspended from metal wires over its center. Sunlight throws the shadow of the ring onto the floor or against the wall. The observer ties a thread to a knob on the central cylinder and stretches it to the outermost wall through the ring's shadow. The markings on the inside of this wall give the Sun's azimuth. At night an observer lies on the floor of the Yantra, positioning himself to place the ring between his eye and the starry object. He notes where his eye is placed, then runs the thread between the cylinder's knob and the wall to locate the azimuth.

But as with the armillary bowls, Singh eventually devised a better way to measure azimuths. This resulted in a pair of instruments known as the Ram Yantras. In each, the cylinder is stone and masonry and stands about 10 feet high. Twelve vertical slabs alternate with arched door-like spaces of equal width, running from the ground to the top ring. These Yantras resemble twin Stonehenges or miniature round Colosseums.

An aerial view of the insides would show radiating spoked aisles alternating with slabs of what now serves as the instrument's floor. The floor comes to about waist level, enabling an observer to move about the instrument fairly easily. The entrance to each passageway is the door-like opening in the outside wall. Like the Jai Yantras, an aisle in one instrument is a marble slab in the other.

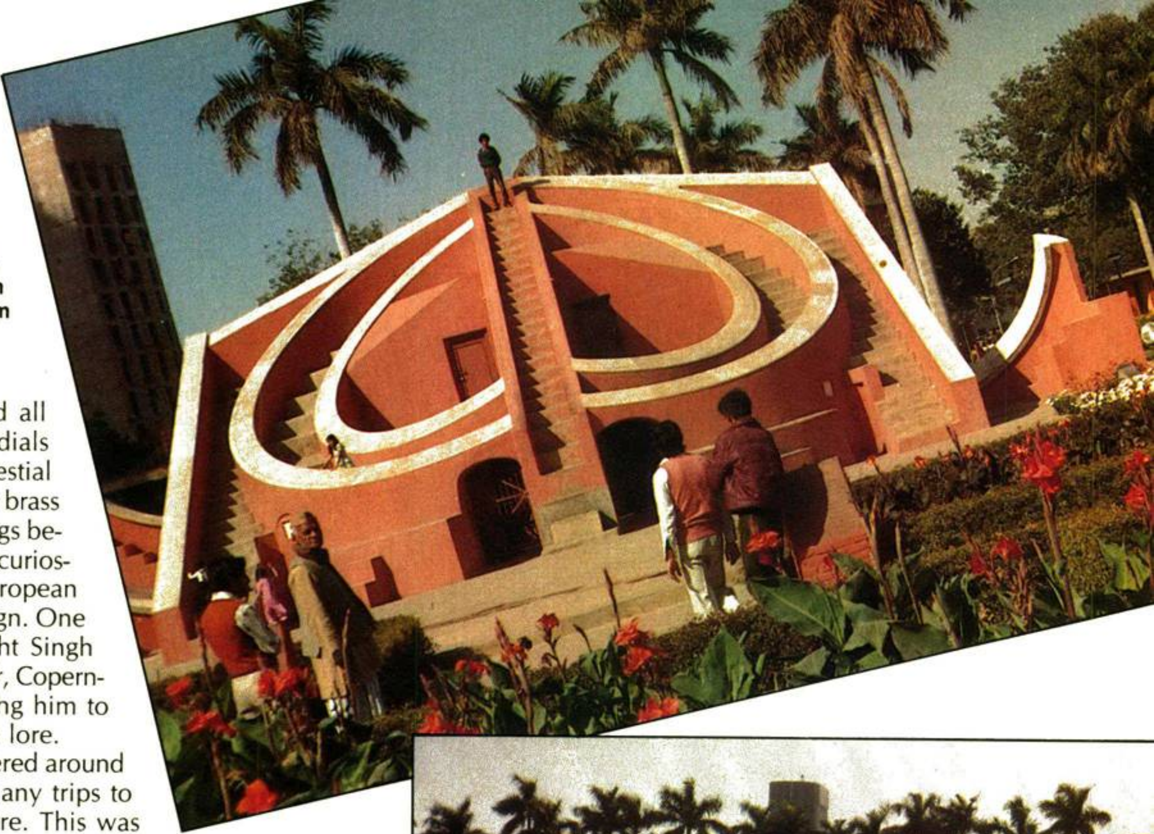
Singh refined the Digamsha Yantras still further. A string or thread was no longer needed to find an object's azimuth, since the floor and the walls were now graduated. In addition, horizontal markings running across the floor and walls also told the object's altitude. Altitude is 0° for an object whose shadow falls on the top edge of the outside wall and increases to 45° as the shadow glides down to where the wall meets the floor at a right angle. From then on, altitude must be read off the floor and reaches 90° when an object is directly overhead.

Despite Jai Singh's strong preference for masonry instruments — he felt that size was the key to accuracy and that massive stonework would best hold the alignments — there are also examples of finely-detailed metal work at Jaipur. For example, the Krantivritti Yantra is an ecliptic instrument similar to that known in the West as a torquetum; it consists of a pair of circular metal frames mounted on a masonry foundation. The part of the frame fixed to the stone lies in the equatorial plane. The rotating upper section lies in the ecliptic plane. By placing a detachable sighting device in the outer frame and turning the instrument to sight the celestial object, its ecliptic latitude and longitude can be determined.

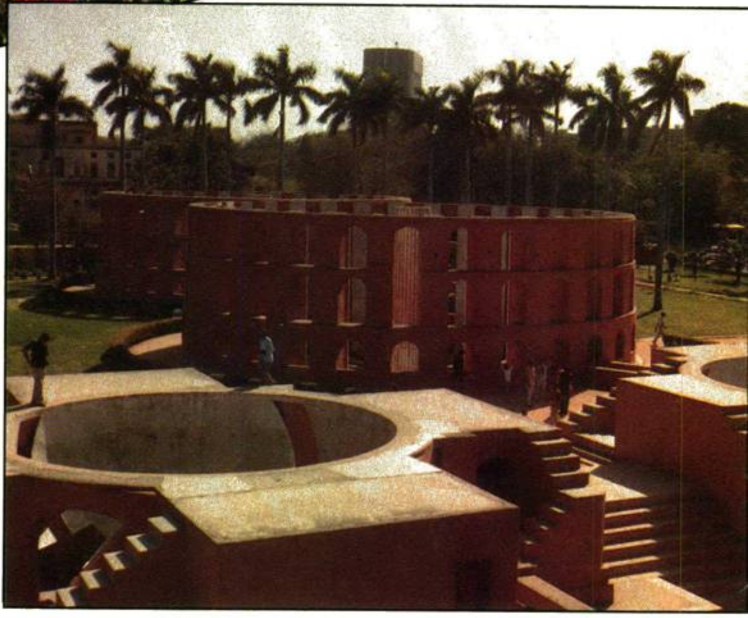
Nearby are twin Chakra Yantras, standing side by side. These are equatorials: each consists of a six-foot metal circle aligned on the north pole. The south end of the polar axis has an hour angle dial; a brass tube for sighting passes through the center of the metal circle, swinging up and down in declination. Scales show the object's declination and hour angle.

The Unnatamsha Yantra is an imposing metal circle, about 15 feet in diameter and suspended over a pit. By looking through a hole in the instrument at the celestial target, the object's altitude can be found.

Singh's favorite metal instrument was a seven-foot iron astrolabe called the Yantra Raj, or "the king of the instruments." This metal celestial map, suspended from stone masonry, inspired Singh to write two volumes on its usefulness. Though its markings are now corroded and



At Jai Singh's Delhi observatory is the strange and marvelous Misra Yantra, many instruments in one. Below: Beyond the bowls of the Delhi Jai Prakash Yantras lie the two Ram Yantras.



effaced, it originally held all the necessary scales and dials for finding an object's celestial position. (An equally large brass companion astrolabe hangs beside it.) This astronomical curiosity attracted several European visitors during Singh's reign. One Portuguese tourist brought Singh the works of Tycho, Kepler, Copernicus, and Galileo, enabling him to expand his library of sky lore.

My stay in India centered around New Delhi, so I made many trips to Singh's *jantar mantar* there. This was his first observatory and served as a prototype for his grander efforts in later years. Though it is smaller and has fewer instruments than the others, a feeling of awe and wonder pervades this observatory as well. Its giant sundial, while not quite as big as Jaipur's, rises majestically out of a pool of water. The round Ram Yantras, the bowl-like Jai Prakesh Yantras, and other devices similar to Jaipur's, can also be found here.

The Delhi observatory offers one instrument that Singh chose not to include in his Jaipur monuments. The Misra Yantra ("mixed instrument") may well be the strangest looking of all his creations as it combines several instruments in one structure. The side walls cast shadows on twisting quadrants. An iron peg juts from the eastern side of a north-south wall for altitude measurements. The north wall slopes 5° south of the zenith so that at the summer solstice, the Sun peeks over it and briefly casts a shadow from which horoscopic measurements can be made. So unique is this composite Yantra that India has used it as a symbol of New Delhi — and of the country itself. Printed on Indian aerogram letters, for example, is a drawing of the Misra Yantra; this versatile device was also used as a symbol for the inaugural Asian Games hosted by New Delhi in 1951.

For the traveler in India, two considerations — apart from the sheer delight in seeing Jai Singh's handiwork — make visiting a *jantar mantar* easy and enjoyable. First, you don't have to hire a guide. You can spend all day moving at your own speed in whatever direction you want. Guides are available, of course; for two rupees (about 20 cents) you can receive an individual tour. I found that some questions about the more complex applications of the instruments stumped my guide, but on the whole he supplied adequate answers. There is no time limit to your guide's attendance except reasonable courtesy.

The second feature of the *jantar mantar* that makes the museum come alive is that there are almost no restrictions on where you can go. You can follow Jai Singh's footsteps up some staircases on the Samrat Yantra and inside the cylinders of the Ram Yantra. The only off-limit areas are those too high for safety or too breakable to risk an uncaring tourist's touch.

But I left on a sad note: people who are unaware of, or simply don't care about, the rich heritage Jai Singh bequeathed them are taking steps to overshadow the past — literally. Office buildings now under construction will soon rise high enough to shadow the Misra Yantra. Even though they are no longer used for measurements, this instrument's dials do not belong under an artificial cloud.

In the struggle of old against new, the loser is the legacy of Jai Singh. Yet his dedication to astronomy, though dimmed by modernity, will remain a victorious achievement — as marvelous and proud and solid as the stones of his instruments.

Stephen Deitmer is a free-lance editor and writer working in New York City. He has visited India twice, filling the evenings by studying more southerly skies with binoculars.

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King Mongkut's Solar Eclipse

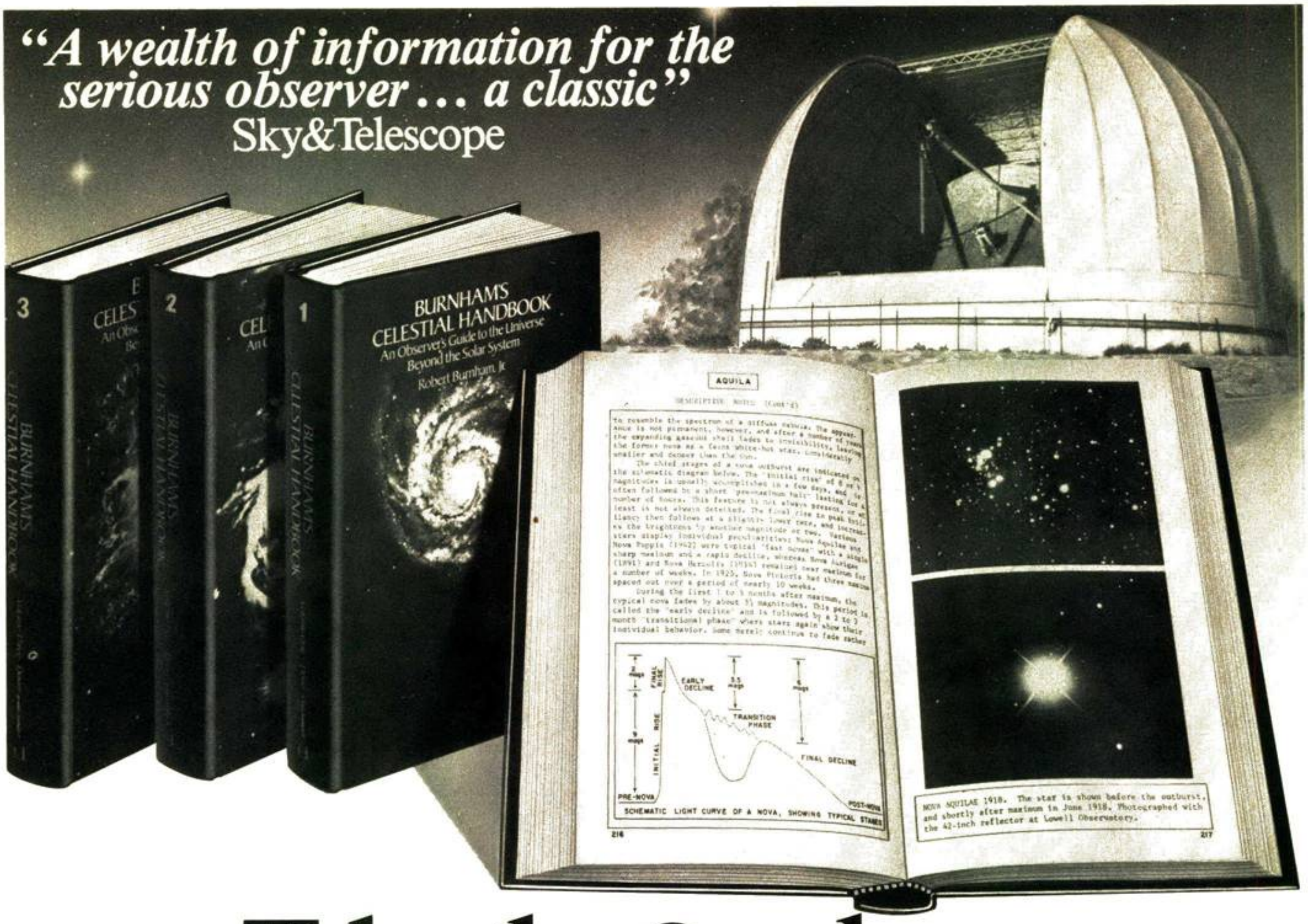
In 1868, His Royal Highness Somedetch Phra Paramendr Maha Mongkut, King of Siam, issued a thousand invitations to his friends to join him at Sun Roi Yot, a jungle observatory 140 miles south of Bangkok. Local dignitaries, missionaries from France and America, and a group of French astronomers received the following note:

"I consider this is the great opportunity to have fulfillment of my pleasure and desire for interview with said noble friends in person, as the total eclipse of the Sun of 18th August will be most remarkable and interesting and its duration about noon will be at How Wan, longitude east 99° 39′ and latitude north 11° 39′, where I will go to wait to see the said eclipse. I wish to write you an invitation to be in accompany with me thither upon that time."

Slanderously misportrayed as the cruel, capricious, and tirading monarch in the musical drama *The King and I*, King Mongkut was actually a remarkable and enlightened ruler. As a young abbot in a Buddhist monastery, he studied history, geography, mathematics, and literature in Thai, Sanskrit, Pali, and Laotian. A Catholic missionary taught him Latin and French, and Rev. Dan Beach Bradley of New York taught him English.

At the age of 46, he abandoned his saffron robe and assumed the responsibility of ruler. Despite the burdening affairs of state, he and his Prime Minister pursued the study of astronomy. The monastery's scientific sources had been limited to Peguan and Thai writings on astronomy translated from ancient Hindu books, but the King also obtained modern text books as well as a telescope from France. He had an observatory built on a hill at his summer palace near

King Mongkut (1804-1868)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Pelchaburi, where he recorded the positions of the stars and the Sun.

King Mongkut was particularly interested in eclipses. He claimed he could "calculate and project eclipses of Sun and Moon, occultations of planets and some fixed stars of first and second-magnitude of which the immersion and emersion from the limb of the illuminated Moon can be seen by naked eye for every place of which longitude and latitude are certainly known."

Relatively alone in his enlightened scientific knowledge, the King was surrounded by astrologers and soothsayers who gravely doubted accurate predictions of eclipses could be made. The traditional belief was that a princess guarded the Sun. An eclipse occurred whenever a giant demon named Rahoo captured the princess and seized her jewel (the Sun), devouring it. It could only be recovered by beating on drums, ringing bells, and making other loud sounds to frighten Rahoo and make him disgorge the Sun. The fortune tellers and mystics also taught the people that an eclipse was an evil omen and always forecast disaster for the nation.

When King Mongkut found that an eclipse of the Sun would be total over parts of his kingdom on August 18, 1868, he took this opportunity to demonstrate to his people the accuracy and value of scientific knowledge. Priding himself on his astronomical pursuits, he would also show the west that a scientist ruled Siam.

A stretch of swampy shore, backed by jungle and mountain, lay near the center line of totality and was therefore chosen as the observation site. The area was called Sun Roi Yot ("300 peaks"); its highest point was a hill called Hua Wan ("Whale's Head") where the guests could stand to view the eclipse.

Compared to today's eclipse expeditions, the King's preparations were royally extravagant. Weeks in advance, hundreds of workmen were sent to clear the jungle surrounding the site and set up camp. Forty elephants were brought overland to do the heavy work. Along the two mile stretch of beach, wooden houses were erected. At the northern end was the Royal Pavillion, draped in scarlet cloth and surrounded by a stockade 15 feet high. Guest houses, tents, and pavillions pushed the cost to almost $1,000,000. No effort or expense was spared to make the guests comfortable.

As eclipse day neared, King Mongkut and his entourage arrived by ship a few days early. He was accompanied by his 15-year-old son and future heir, members of his court, the doubting astrologers, and several of his 35 wives.

August 18th dawned clear and bright, but clouds soon began to gather. By the time of first contact, the sky was overcast and the Sun invisible. The Frenchmen were in despair. They had spent many months in preparation and had traveled 10,000 miles for this glorious moment — and now this! *"Tous nous semblai perdu,"* the director reported. All was apparently lost.

In desperation and as a last resort, the Prime Minister called upon the King's missionary friends to pray "that the overruling Providence may be pleased to disperse the clouds long enough to afford us a good view of the grandest of eclipses." Suddenly, the clouds parted and the Sun appeared. The Moon had already covered almost a twentieth of the Sun's disk. The rest of the eclipse proceeded without interference. Totality lasted 6 minutes and 46 seconds; it became so dark that stars could be seen in the sky. "Totality with all the glory of the corona and the flaming protuberances was seen under perfect conditions... *Le ciel devient magnifique!"*

Jubilant over the success of his prediction, the King had cannons fired during totality; the blare of pipes, trumpets, drums, and fireworks added to the din. Excitement ran high among the spectators. The Prime Minister, overcome by the awe-inspiring sight, turned to the Thai bystanders and shouted, "*Now* will you believe the foreigners?"

The King was most pleased that his predictions had been so accurate; in fact, his calculation for the duration was two seconds closer to reality than that predicted by the French scientists.

King Mongkut had dramatically proven that an eclipse of the Sun could be predicted. But the astrologers still were not completely convinced — hadn't there been cannons, drums, and fireworks during totality? Of course Rahoo was frightened by these noises and returned the Sun! Furthermore, a serious disaster *did* befall the nation soon after the eclipse.

The site of the eclipse party was swampy and mosquito-infested. Soon after returning home, many guests suffered attacks of malaria. King Mongkut, too, became ill. Only a few weeks after his great scientific triumph, he died. This was truly a disaster for the nation because the Thais lost an enlightened and progressive ruler.

Today in Thailand, King Mongkut — also known as Rama IV — is a national hero. Reminders of his interest in astronomy are still evident. His observatory on Palace Hill near Pelchaburi is a national shrine. When another total eclipse of the Sun occurred over Thailand, in 1933, Mongkut's grandson King Prajadhepok viewed it with his grandfather's historic telescope. On a wall of the Rajapradich Temple in Bangkok there is a mural depicting the eclipse of 1868. And on the outskirts of Bangkok, Mongkut's descendants have built in his memory a modern observatory and planetarium. School children from all over Thailand go there to learn more about the Moon, the stars, and the universe.

Olga Lindberg
Bowmansville, NY

Astronomy in a Third World Country

Yes, astronomy is alive and well in the third world — but no, it is decidedly not "big science." I speak from the perspective of one small third-world country, Barbados, where I have lived since 1971.

A question I've often been asked by people from the "first world" is why I ever chose to live in an astronomical backwater. Well, one good reason I can think of (eat your hearts out!) is the large proportion of clear nights and the pristine, unpolluted skies of the Caribbean. Also, being situated at 13° north latitude lets me view almost all the constellations at one time or other — from Ursas Major and Minor down to Crux, the Southern Cross.

Apart from this, however, there is another reason — the need to spread the astronomical gospel. Barbados has a literacy rate of 98 percent and is perhaps unique among third-world countries in this respect. The trouble is that a great deal of this literacy is squandered on pseudoscience: astrology, Velikovsky, von Daniken, and the like. Living in Barbados, then, offers a singular opportunity to expose a large cross-section of the population to what real astronomy has to say. It also incurs some singular responsibilities — like explaining, at three o'clock in the morning, to an excited phone caller just what a bolide is.

Of course, some of my cynical friends chide me about relishing the chance to be the big fish in a small pond — and this may well be one factor enticing me to remain here. I can't deny that I am the only person around here with a university qualification in astronomy. But as I've noted, there is a price to pay for this.

What are the problems encountered in promoting astronomy in a country such as Barbados? Perhaps the biggest

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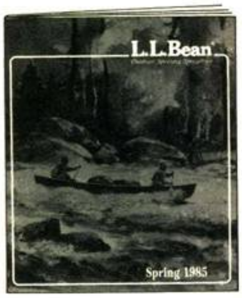

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one is a misperception on the part of the population. For most Barbadians, astronomy is either something you use to work out a horoscope, or it is aimless "stargazing" — a gross irrelevancy to the needs of a developing country. You can deal with the first attitude by means of courses, articles, and lectures. But the second is much more difficult to counter.

Every time I lecture, at least one questioner raises the plaintive cry, "But what *use* is it?" Answering that through astronomy, we can extend the boundaries of our knowledge never seems to impress them. At the same time, I can't bring myself to trot out the standard line that it's brought us Teflon frying pans and better computers. You shouldn't have to defend astronomy by appealing to utility. I realize that the relevance of astronomy and its funding may also be challenged in the U.S., but this is not so critical since there are many ways for American researchers to solicit funds. In Barbados, extremely limited funds mean that utility and application are the main criteria for judging every research proposal.

Given the problems and obstacles, it's natural to wonder if there really is a place for astronomy in a third-world country.

A bias toward the practical fosters misperceptions even in the scientific community. A physicist, for example, who has the courage to switch from solar crop driers to cosmology, will daily encounter doubtful looks from his colleagues. A graduate student who elects to do research in some branch of astronomy effectively cuts himself off from almost all support. I'm speaking here about more than just money; psychological support — the encouragement and appreciation of the department staff for one's research work — is missing, too.

I was a post-graduate student in the department of physics at the University of the West Indies for the past four years. Apart from my chief supervisor, an astronomer on the neighboring island of Trinidad, I doubt if my research into the relationship between solar flares and sunspots has been appreciated by a single staff member. I have learned to accept this, but find it hard to swallow when a lack of understanding among my colleagues leads them to think what I'm doing isn't "real" physics. Even being published in a international journal such as *Solar Physics* doesn't seem to nullify this view.

At present, the sole repository of astronomical knowledge in Barbados is the Barbados Astronomical Society, based at the island's Harry Bayley Observatory — the only observatory located in the eastern Caribbean. The society was founded in 1956 by Dr. Harry Bayley and W. Eustace Thomas as a non-profit organization of amateur astronomers. The observatory was completed in 1963, following the anonymous donation of a parcel of land and an energetic fund-raising campaign by members.

Since then, the observatory has been greatly expanded — a second story addition with library and darkroom was built and a new C-14 telescope put into operation. The problem for the last several years has been underuse. This is the natural consequence of having a small, highly-active core of members out of a total of perhaps 50. The active members have certainly done a lot, but after countless lectures, basic courses, workshops, and telescope observing sessions, there is still hardly more than spectatorship from the majority of Society members. Worse yet, most of us who have run these enterprises — at times, a little frantically — are now pretty burned out.

The root cause of this might be a lack of a steady exposure to astronomy in the schools. For most students in the island's 20-odd secondary schools, their only look at astronomy comes in a brief section of basic-level physics that deals with lunar and solar eclipses. As an educator in the island for 14 years, it always struck me as ironic that a pupil could explain clearly all the facets of electrical impedance — yet didn't know the Sun was a star.

Attempting to correct this, I developed a basic astronomy syllabus in 1977. This was to be part of a larger science syllabus, to be introduced into a number of schools in 1978. None of the topics was exotic: tides, eclipses, seasons, longitude and time systems, the planets, and constellations. In subsequent teacher training workshops, however, I was told again and again that my proposed syllabus was "too ambitious" or "too revolutionary." One chemistry teacher complained, "It exceeds the capabilities of my students." (But evidently, the study of rates of reaction and chemical equilibrium didn't!)

Despite the objections, astronomy instruction began in the high schools in the spring of 1978. By 1981, however, it became clear that the experiment had failed. It turned out that the science teachers were often omitting the astronomy sections of the syllabus. After several years, they realized that they could safely ignore astronomy — it was seldom asked for in exams — and give preference to areas where they were knowledgeably more comfortable. These were usually — wouldn't you know? — the sections on chemistry and biology. Today, astronomy is once more almost nonexistent in secondary schools.

A stunning defeat? I suppose so. But nevertheless, for three or four years hundreds of students were exposed to a broader perspective of the universe. For those few weeks, their eyes turned heavenward and they were part of something bigger — bigger than themselves and bigger than the tiny island of Barbados. A few of these students have even gone on to pursue astronomy-related careers in land-surveying and meteorology. Personally, I think the effort was well worth it.

A graduate student who elects to do research in some branch of astronomy effectively cuts himself off from almost all support.

Given the problems and obstacles, it's natural to wonder if there really *is* a place for astronomy in a third-world country. I believe there is. The astronomical society opens its observatory to the public once a week, so a forum for astronomy education still exists. Apart from the small band of active participants at the observatory, there are also people in Barbadian society who are interested. They stop my wife and me on the street to mention how they appreciated our last article in the newspaper — they never realized stars were so big and so distant! And they continue to call us at odd hours to find out when a certain planet will be visible, or when the next lunar eclipse will occur.

As for me, while this interest and hunger for more knowledge persists, *I'll remain in Barbados. Excuse me for* now — I think I hear the phone!

Philip A. Stahl
St. Michael, Barbados, West Indies

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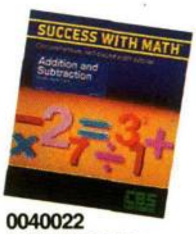
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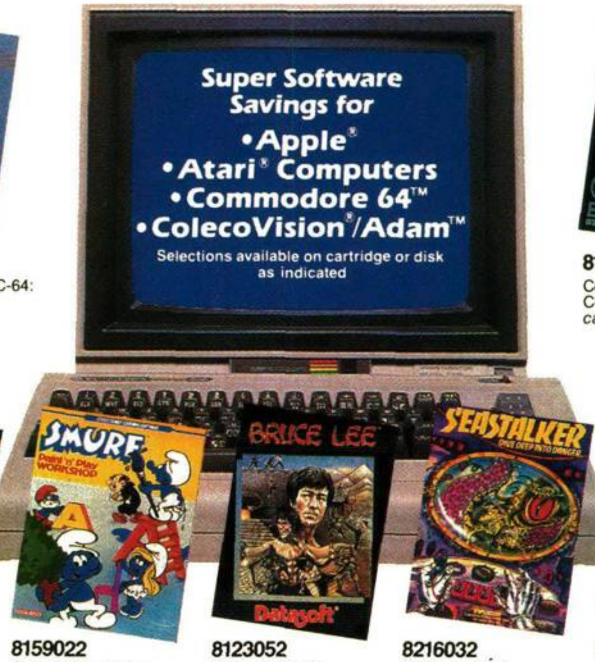
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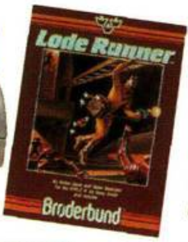
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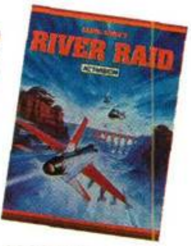
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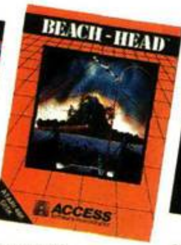
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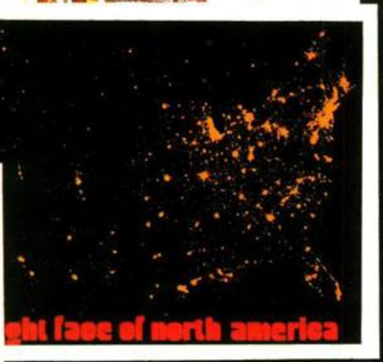

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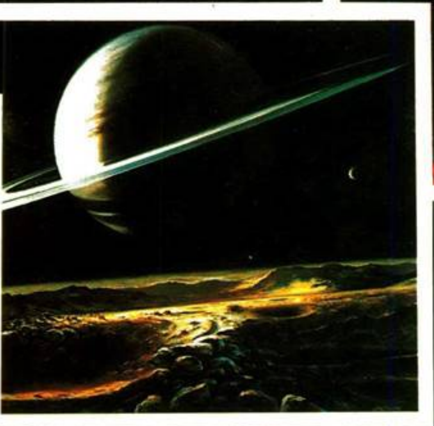

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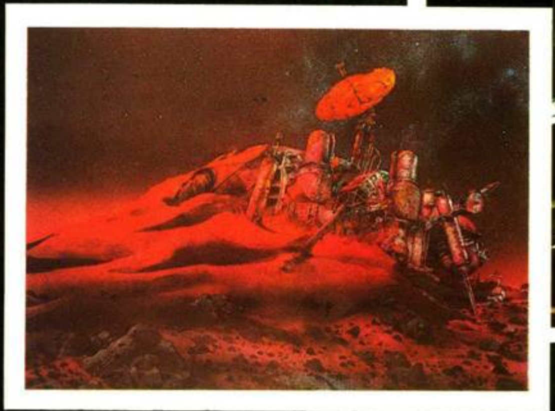

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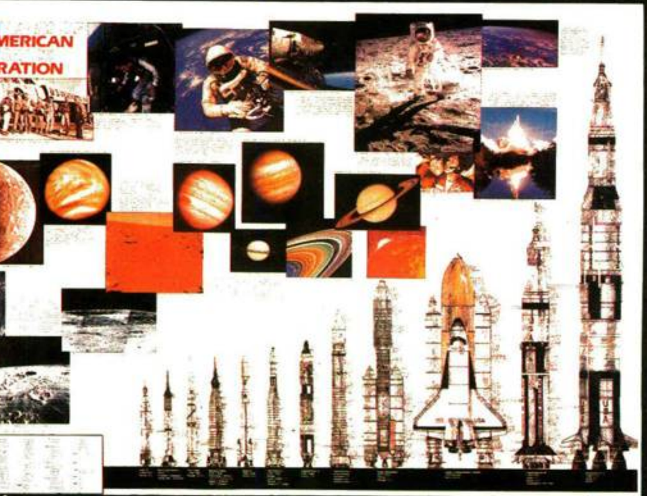

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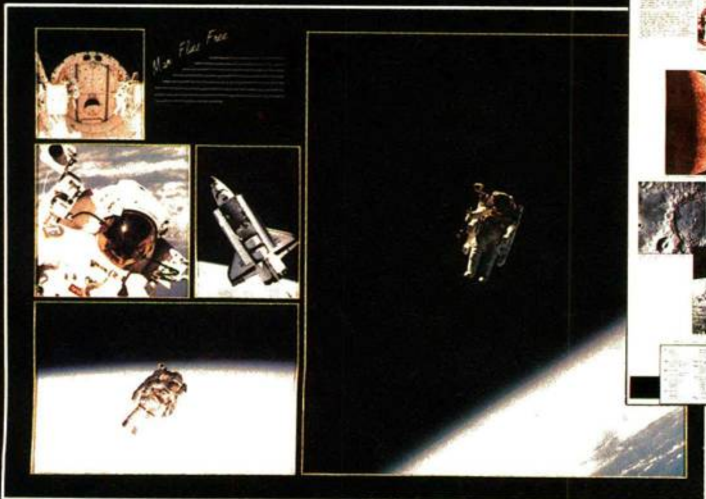

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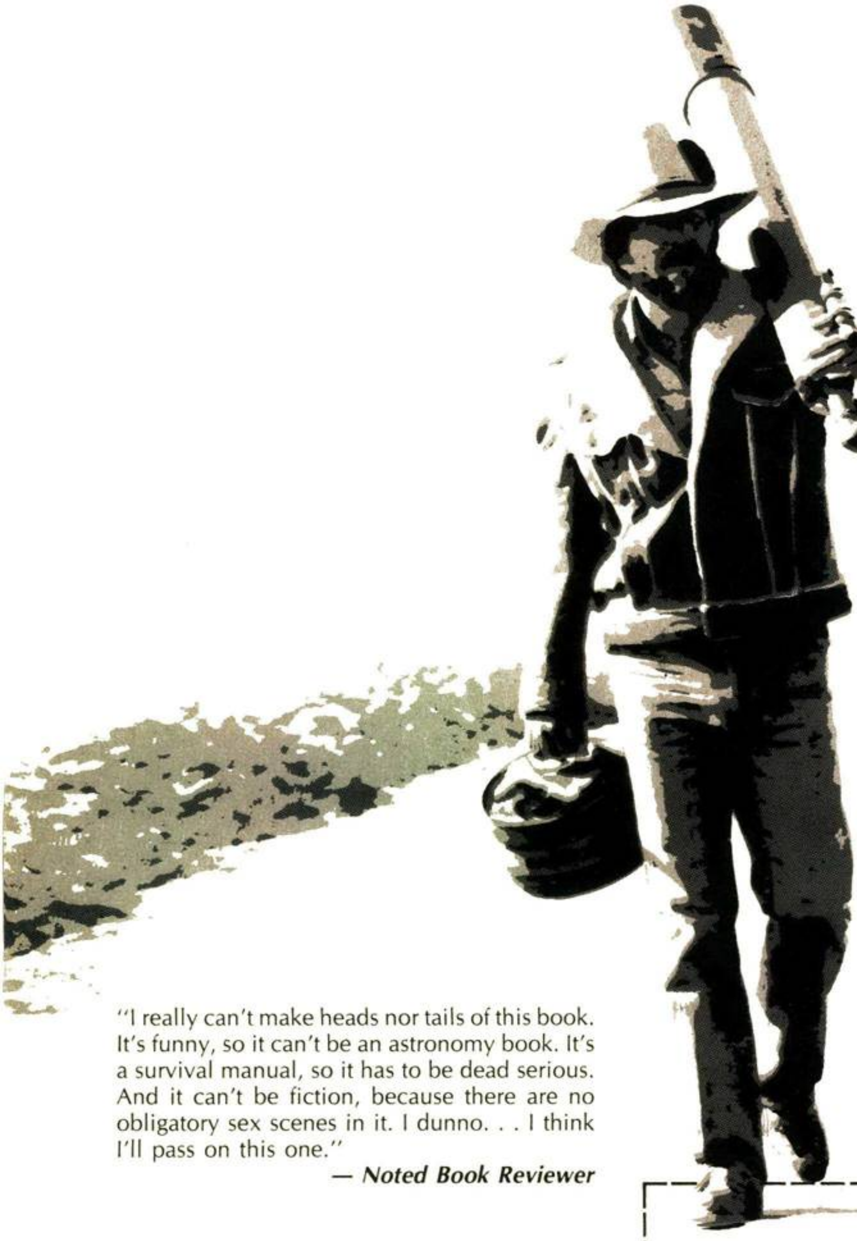

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— Doris Fulton, wife of the author

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ASTRONOMY
In Focus

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Sir / After 22 years of distributing NASA slides, films, and videotapes, we think it's time to retire.

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Gerry and Joe Bonica
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Soviet Lunar Update

Sir / I'd like to add a few additional facts to my "Soviets to the Moon" feature in last month's issue. The Zond spacecraft was clearly the Soviets lunar orbiting spacecraft, but who was the crew for the anticipated flights? In the April 1981 issue of *Ogonyok* magazine, published on the 20th anniversary of Gagarin's manned orbital flight, cosmonaut Vitali Sevastyanov, who flew on both Soyuz 9 and 18, confirmed that the Soviets had a manned lunar orbit program.

In the article, he revealed that the Zond team was formed in mid-1967 and included Aleksei Leonov, Valeri Bykovsky, Pavel Popovich, Georgi Dobrovolsky, Yuri Artyukhin, Oleg Makarov, Nikolai Rukavishnikov, Georgi Grechko, Pyotr Klimuk, and Sevastyanov himself as training manager. Sevastyanov said he was replaced as manager by Pavel Belyayev later that year, when he transferred to the Earth-orbital program.

Peter Pesavento
Emlenton, Pennsylvania

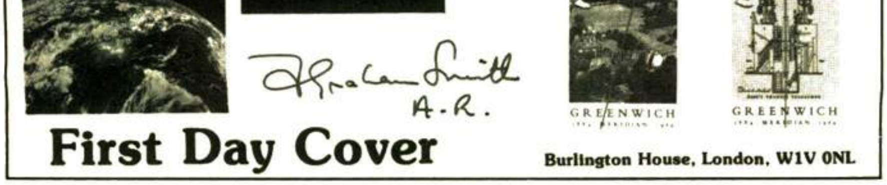
A Stellafane Experience

Sir / As an amateur astronomer who attended Stellafane for the first time this year, I thought you might be interested in my reaction. For those not familiar with the site, Stellafane is held at the clubhouse of the Springfield Telescope Makers on Breezy Hill, just outside Springfield, Vermont. The setting provides a sense of history as well as inspirational scenery. The spirit of Russell Porter, instrumental in the design of the 200-inch Palomar telescope and founder of the Springfield group, seems to be omnipresent.

The first thing I felt as I walked up the hill was that important things had happened here. I felt like a student of history standing in Independence Hall. To a large degree, American amateur telescope-making was born here. And indeed, it continues to thrive; there were many telescopes of conventional design made from meticulously-crafted parts. But the real fun came in talking with folks who had done something really innovative, either in design or with use of materials. I came away with many ideas for a next telescope.

Part of the flavor of Stellafane results from its strictly non-commercial nature. No manufacturers' representatives were present and the only items for sale were found on swap tables at the bottom of the hill. There was a great gathering of the bits and pieces that exemplify amateur astronomy on those tables. Brass tubing, Teflon, mirror blanks and even weight-driven clock drives — and the price was usually right. It was a real test of self-control to walk from table to table without spending my travel money!

Among this year's events were a variety of talks given by the well-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This British first-day cover commemorates the centenary of the Greenwich meridian and features stamps showing (clockwise, from top left): the meridian passing through Africa, a map showing its location in England, a drawing of Airy's transit telescope, and the meridian crossing the Royal Greenwich Observatory. Its Saturn-shaped cancellation — produced by the British Astronomical Association — is postmarked June 26, 1984 and the cover is signed by the Astronomer Royal, F. Graham Smith. Courtesy Robert E. Cox.

known, and the not so well-known, in amateur astronomy. Stellafane is a place where the names you've seen in print transform into real people; I enjoyed seeing Ben Mayer and Walter Scott Houston, and a host of other prominent amateurs. Many had important things to say, and there was always a large audience tuned in.

So what does a first-timer at Stellafane feel as he packs up for the long trip home? I felt a renewed sense of vigor for finishing my stalled telescope project and, even more important, I felt a need to go home and share what I learned from the crowd at Stellafane. And who knows, maybe someday something *I've* built will sit beside those masterpieces on Breezy Hill . . . .

Doug Gegen
Murray, KY

Anglo vs. UK

Sir / On September 20-21 in St. Andrews, a conference was held concerning the Anglo-Australian Telescope (AAT). Representatives of both boards, British and Australian, were present as well as the professionals on the project.

In reference to this, I wish to make a complaint about the indiscriminate misuse of the term "Anglo." Anglo refers to anything of England, and not of the UK or Britain as a whole. The AAT and the Anglo-Australian Observatory (AAO) are funded on the UK side by the Science and Engineering Research Council. This funding comes from *all* UK taxpayers: Scottish, Welsh, North Irish, as well as English. The UKIRT and UK Schmidt instruments are named more correctly as they use "UK." (Is this because they are run from Edinburgh?) Perhaps it would be better to rename the AAT and AAO using "UK"— and scrap forever the unfair and unrepresentative term "Anglo." After all, wouldn't there be loud protests from the English astronomical population if UKIRT were renamed the "Scottish Infared Telescope" or "Scotland-Hawaii-Telescope"? There are many UK amateurs and professionals who read ASTRONOMY and should be informed of this callous disregard for Scottish astronomy.

Graham Young,
Secretary
Dundee Astronomical Society

Are We Afraid of the Dark?

Sir / I've followed the alien contact debate with interest and some dismay at the paranoia expressed. Mr. Ostrower (October's In Focus) suggests that alien mentalities would be "unknowable" and denies that "morality" could have anything to do with alien thinking; he then concludes with a leap of logic that this makes them a threat.

Let's remember that we're talking about life forms which have learned to manage flight, atomic energy, and computers if they're at a level to be able to reach us. Technology *is* a culture. Flight through air at a certain pressure imposes certain engineering requirements. These in turn require certain societal and cultural developments to produce an industry capable of handling the engineering. Space flight works the same way.

Whatever its mentality, if we meet it in space then at least it hasn't blown itself up. It certainly has enough raw materials to satisfy its needs — derived from space itself. And if it's going to trek farther than two parsecs to destroy us, I submit it would come here whether or not we contacted it — it's probably wandering from one G-class star to another, just looking for trouble.

We live *in* this universe whether or not we're afraid of the dark. If aliens can get here at our invitation, they probably have optics and instruments immeasurably better than ours. If there's something in the neighborhood that's really aggressive *and* capable of starflight, it need only scan and strike. I suggest we would serve ourselves better to send out a polite hello lest our silence be mistaken for surliness.

C.J. Cherryh
Edmond, Oklahoma

Ooops!

On page 75 of the August issue, the titles "Epoch 1950" and "Epoch 2000" were swapped. Epoch 2000 should be the upper title. The r.a. lines were also mislabeled: 17 should read 18 and 18 should read 19.

Behind the Scenes

A Missing Star

A letter from Scott Aldridge of the Muscle Shoals Astronomical Society recently brought us sad news: long-time ASTRONOMY contributor Earle Dodds passed away September 27, 1984. Readers will recognize Earle as the author of "The Coming of Epoch 2000" (August 1984)* and the five-part series, "Exploring the Constellations," which ended last month.

Earle was more than a writer to us. Over the years, he also became a friend. His letters — which fill a file nearly two inches thick — were always witty, and rich with ideas and suggestions. We looked forward to meeting him at ALCON this year, but he was too ill to attend.

"My earliest recollection of anything astronomical is the visitation of Halley's Comet in 1910," he wrote in 1980. "I was all of seven years old at the time, and I can well remember the brilliant head of the comet and its long sweeping tail."

Earle's first telescope, a handmade 6" f/8 Newtonian named Peepsight, was completed in 1926. But his civil engineering career took him around the country, "so Peepsight II was crated up . . . for many, many years." In the 70s, Earle's astronomical interest re-emerged; and in 1975, when he independently discovered Nova Cygni, it blossomed. With the help of Ed Hooper, his "backyard neighbor," he soon constructed Peepsight III and then Peepsight IV. He joined the Muscle Shoals Astronomical Society, established "Mockingbird Hill Observatory" in his back yard, and started writing to ASTRONOMY.

Possibly because his own interest had lain dormant so long, Earle was eager to help novices get a start in astronomy. "I would like to help beginners avoid the false starts and blind alleys that I have had," he wrote in 1979. "I'm sure I'd be much further along if I had only had a little elementary help a few years ago."

Earle was over 80 at the time of his death — but age didn't matter. His interest, enthusiasm, and love of astronomy are timeless.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

---

*Earle's earlier articles include "Image Orientation" (April 1981), "How to Find 'Em Even If You Can't See 'Em" (August 1980), and "A Simple Low-Cost Mounting That Lets You Sit Down While You Observe" (January 1979). Earle's article on Mockingbird Hill Observatory originally appeared in *Telescope Making #5* and was later reprinted in our booklet, "How To Build Your Own Observatory."

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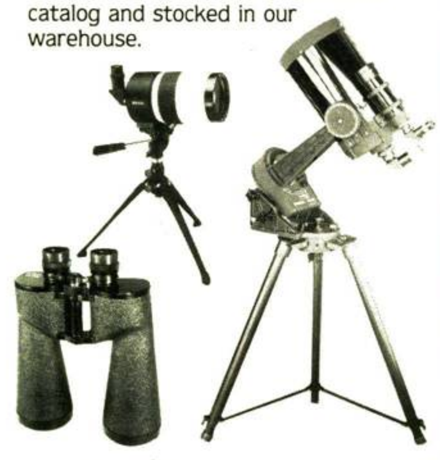

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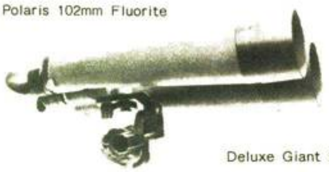

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Exposure in Astrophotography

The question that faces every astrophotographer each time the shutter button is pressed is, "How long must I expose?" Exposure is crucial: too much light striking the film results in a negative too dark to use (or a slide too light), and too little fails to form any image at all. Between the extremes lies a broad range of useful exposures. Getting the best results — an image neither too light nor too dark — depends on making precisely the right exposure. But just what is the "right" exposure in astrophotography?

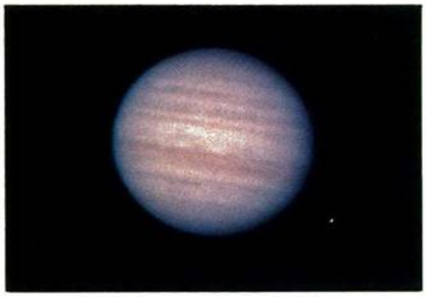
The terminology is somewhat misleading, because the exposure that's "right" isn't necessarily right for every purpose. Astrophotography is a specialized type of photography — the photography of bright objects on a dark background, of rugged landscapes, and of clouds on other planets. Your goal is to expose the film so significant detail in the negative (or slide) falls in the middle range of densities that negative or slide can produce.

Consider a specific example: you're making a slide of the constellation Cygnus centered on the star Deneb, using an ordinary camera attached to your telescope for piggyback tracking. What, you ask, is the correct exposure?

There are at least three answers. If you want to show only the bright stars and constellations, then the correct exposure is short — 10 seconds or so. If you want to show fairly faint stars, say down to 10th magnitude (as for a nova search), an exposure between two and five minutes will suffice with most cameras, if you use fast film. But if you want to show the starclouds and nebulae of the Milky Way, you may need to expose for 45 minutes or more (providing light pollution does not render the Milky Way altogether invisible).

Each slide is properly exposed for the purpose it was taken — but over- or underexposed for the others. In each case, the significant detail (bright stars, faint stars, or the Milky Way) lies in the middle of the film's range of densities, rather than at the light or dark end.

How can you recognize a properly exposed slide or negative? Two rules of thumb apply — one for slides and one for negatives. For slides: If you can see everything you want to see in the slide when you place it on a bright lightbox without blocking the area around it, it's properly exposed. For negatives: If you can read fine newspaper print through the darkest area containing significant detail in a 35mm negative held an inch from the paper, it's properly exposed. Slides that are darker than desirable may still look beautiful when shown on a slide projector in a darkened room, and negatives darker than they should be can still yield successful prints. Slides that are overexposed are generally washed out in color. Negatives without detail in important shadows (that is, the dark areas you're interested in) are underexposed.



If the exposure is not right, your pictures won't show all the detail they should have. In this photo, the exposure was right and the image scale more than adequate. Photo by Charles Capen.

Let's apply these criteria to a few astrophotos and see how they work. Imagine you have taken both slides and negatives of Jupiter. All of them are in good focus, but some are dark and some are light because you varied the exposure. How can you find out which is the best exposure? First, place the slides on a lightbox and look at them from 10 to 14 inches away. Next, ask yourself, "Which is the darkest slide that is still light enough to show everything I want to see?" The one you choose has the best exposure. Although much darker pictures may still look pretty good when viewed through projectors, they are actually underexposed and don't represent the best image the film can produce.

Now examine your negatives. You can, of course, see right through the clear backgrounds, but those are not the "significant detail" areas you're looking for. Find a negative where the image of Jupiter is just light enough to read through. If the picture is sharp enough to show cloud belts, bands, and the Great Red Spot, these will show up as subtle variations in the tone of Jupiter's image.

Of course, if you take the same picture to show Jupiter's moons, you need to expose longer. The negative image of Jupiter will be too dark, but Jupiter is no longer the "significant detail." The moons are.

The same exposure criterion applies to star pictures, Milky Way pictures, Moon pictures, and comet pictures. It provides a mid-range density of 1.0 to 1.5 for slides and negatives, and insures that the film is operating in its best performance range.

Correct exposure boils down to letting the right amount of light reach the film. Exposure time can vary over a wide range. In astrophotography, the exposure can lie anywhere between 1/1000 second and 1,000 minutes! By opening the shutter for longer or shorter times, you can control how much light strikes the film. There are limitations, however. The object you're photographing may move or change, blurring the image, or the night may end before you finish a long exposure. Exposures shorter than 1/1000 second are rare. Few shutter mechanisms are quick enough and few astronomical subjects are bright enough to allow shorter exposures. Exposure time provides control of light over a range of roughly 60,000,000 to 1.

Besides exposure time, you can control — with some limitations — the efficiency of the optical system that forms the image. This efficiency is determined by dividing

Brightness "B" Values for Celestial Objects

Lunar Phases:	
Crescent Moon (2-3 days)	10
Crescent Moon (4-5 days)	20
Quarter Moon	40
Gibbous Moon	80
Full Moon	200
Earthshine	0.01
Lunar Eclipse Features:	
Full Moon	200
Edge of Umbra	0.05
Mid-totality (varies)	0.005
Planets:	
Venus	2,000
Mars	60
Jupiter	30
Saturn	10
Uranus	4
Solar Disk:	10,000,000
Solar Eclipse Features:	
Prominences	100
Inner Corona	50
Middle Corona	5
Outer Corona	0.5
Eclipse Sky	0.01
Horizon at Eclipse	0.5
Deep Sky Objects:	
Center of Orion Nebula	0.001
Most Nebulae	0.0001
Middle of M-31	0.0002
Most Galaxies	0.00001
Milky Way	0.00001
Perfect Sky Background	0.000002
Earth Comparison Objects:	
Blue Sky	1,000
Summer Scene	250
Winter Scene	100
Normal Room (night interior)	2

effective focal length by the aperture of the optical system, giving you the so-called f/number. Quality lenses are available in f/numbers as small as f/1. These allow a lot of light to come through and are called "fast" lenses, because you can shorten the exposure time short since there's more light reaching the film. You might not want a fast lens, though; you may want an optical system with a long focal length so you get a large image. The focal length of telescopes is normally between 4.5 and 15 times the aperture, but to achieve the biggest possible images you can use "eyepiece projection" to increase the focal length to 100 times the aperture. Since image brightness depends inversely on the square of the focal ratio, there is a 10,000 to 1 range in image brightness between f/1 and f/100.

Films vary in their sensitivity to light. The fastest films (so-called because exposure times for them can be short) are roughly 1,000 times more light sensitive than the slowest. Slow films offer certain advantages, however; they are less grainy, so the image on them may be sharper. Films are speed-rated by an "ISO rating," determined by the manufacturer in accordance with specifications of the International Standards Organization. The fastest films are ISO 1600, and the slowest is ISO 1 or 2. You should choose a film first on the basis of sharpness. However, if exposure times turn out to be impractically long with a slow (but relatively grainless) film, you'll have to use a faster film.

Finally, an object's brightness determines how you will photograph it. The brightest subject in astronomy — the Sun — is about 10 trillion times brighter than a similar-sized section of pitch-black rural sky. The brightness of the object will force you to choose a film, an f/number, and an exposure setting capable of producing correctly exposed film. You may have to make some tricky trade-offs in terms of cost, exposure, sharpness or practicality to do this, but that's part of the fun of astrophotography.

Obviously, film speed, f/number, and exposure are related. They all influence how dark or light your negative or slide will be. You can, for example, decrease the amount of light reaching the film by changing to a higher f/number (or by your choice of telescope, camera lens, or eyepiece), but must compensate for this by increasing the exposure time. The f/number is often difficult to control in lunar or planetary photography because you need a focal length that gives you an image large enough to show the significant details you want to photograph. And if you're making deep-sky pictures, your telescope or camera lens will dictate the smallest f/number you can use. Most astrophotography requires using relatively fast films — except, of course, for solar photography.

Furthermore, you have no control over the brightness of astronomical subjects. While this probably frustrates studio photographers, everyone else takes it for granted. The only variable you can really control is exposure time. Within limits, you can keep the shutter open as long as you have the energy to stay awake to guide the telescope.

Luckily for astronomers, one simple mathematical equation neatly ties all the exposure variables together. That equation is:

$$E = \frac{f^2}{S \times B}$$

This equation tells you the exposure time, E, in seconds. S is the speed of the film in ISO units, f is the f/number of the optical system, and B is the brightness of the celestial object. You'll find a table giving B values for a variety of celestial subjects at left.

Let's work out a few examples to get the feel of the relationship between the exposure variables. Imagine that you want to photograph the First Quarter Moon with an f/10 Schmidt-Cassegrain using Ektachrome 100 film. First, look up the B value for the First Quarter Moon. It is listed as 40. Now plug the numbers into the equation:

$$E = \frac{10^2}{40 \times 100} = \frac{100}{4000} = \tfrac{1}{40} \text{ second}$$

Since the result is given in seconds, the exposure should be 1/40 second. Most cameras don't have 1/40 second on the shutter speed dial, but 1/30 is close enough. Try 1/15 and 1/60 second exposures, too, and if it's your first try at astrophotography, also experiment with the exposures of 1/8 and 1/125. Bracketing the exposure, as photographers call this practice, is often necessary.

Now you may wonder why, after just doing so much math to find the correct exposure, we immediately urged you to try other exposures. The answer is that you don't know — precisely — what the f/number of your telescope is, what the speed of the film is, or how bright the object is after its light has passed through Earth's atmosphere. The atmosphere may be transmitting as much as 75 percent or as little as 25 percent of an object's light without this being obvious visually. Your telescope's optics may be a bit dirtier — or cleaner — than average. In addition, if you leave film in a hot place for a couple of days, its speed changes and sometimes even doubles. As a result, it's best to bracket until you gain experience.

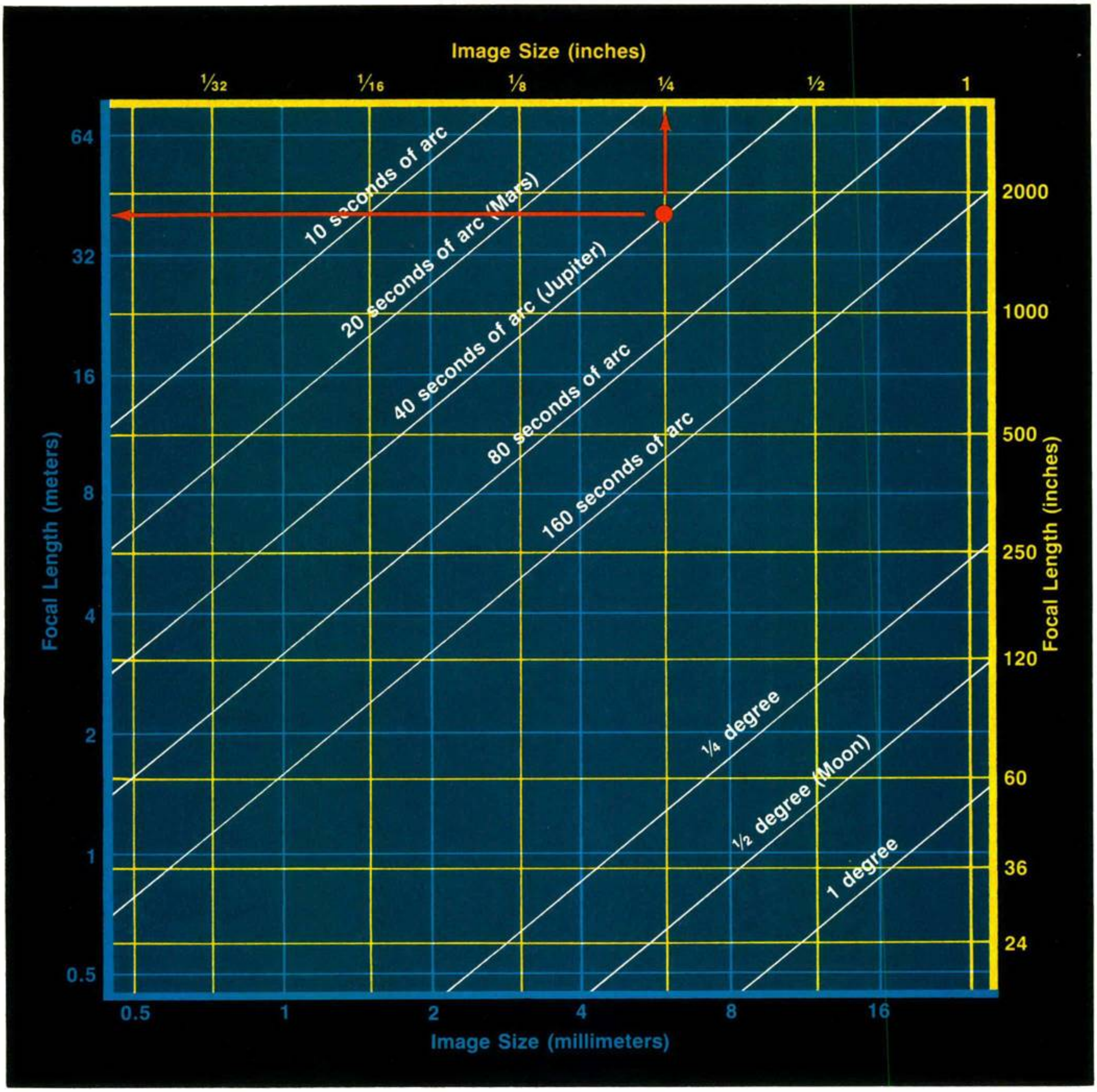
Let's try another example. Suppose you want to photograph the Milky Way with your 28mm wide-angle lens. It's an f/2.5 lens and you plan to use Ektachrome 200 film. The table gives the Milky Way's brightness as 10^{-5}. Plug in the numbers:

$$E = \frac{(2.5)^2}{200 \times 10^{-5}} = 3125 \text{ seconds}$$

The exposure is going to be pretty long — 3,125 seconds is 52 minutes! At this point, you might consider asking yourself: If the slide came out a little darker than it should, wouldn't that be all right? Of course it would; in fact, an exposure of 15 to 20 minutes will probably give you a picture to be proud of. But perhaps you'll rethink the project and try the equation again, this time changing to your 50mm f/1.4 lens and Ektachrome 400 film:

$$E = \frac{(1.4)^2}{400 \times 10^{-5}} = 490 \text{ seconds}$$

Now that's more like it! The new exposure is roughly 8 minutes, reducing the



Suppose you want to photograph Jupiter so the image on film will be large enough to show plenty of detail. Normally ¼ inch, or about 6 mm, is sufficient. Locate this diameter on one of the horizontal scales, move vertically to the diagonal line representing Jupiter's angular size (40 seconds of arc), then cross horizontally to the appropriate focal length scale. This shows a focal length of 40 meters, or 1600 inches, will do the job. With an 8″ SCT, the f/ratio must be 1600/8 = 200 to produce a 6 mm image of Jupiter.

temptation to underexpose. The decreased exposure time also suggests it might be worthwhile to set the lens at f/2 and run for 17 minutes to avoid those "wide-open fuzzies."

You've probably heard that film doesn't record as well in long exposures — well, that's called reciprocity failure. The B value in our equation contains an automatic correction for average reciprocity failure in films. If you find, after making several exposures, that you need more or less exposure than the equation tells you, simply adjust your exposure time.

Once your pictures are coming out to your satisfaction, you can refine the B value for your particular equipment. Using your exposure data, calculate the best B value — for you and your telescope — from this equation:

$$B = \frac{f^2}{S \times E}$$

If you find that your B value varies from the one given in this table, don't worry. There are enough variations in equipment and film that disagreement by a factor of 2 or 3 is both reasonable and common. Once you've calculated it, you can use your own B values for finding exposure times.

Remember that the real value of the equation is to give you a starting place. "How long should I expose?" is a question too vast to face when the exposure might be anything between 1/1000 and 1,000 seconds. But with a starting point that's almost certain to produce decent results — providing you bracket your exposures — you can proceed with confidence in astrophotography.

— Richard Berry

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Reviews

Soviet Space Programs: 1976-80
Congressional Research Service
461 pages, paperback, $7.50
U.S. Government Printing Office (1982)

Space flight is an intensely political activity, intimately tied up in superpower rivalry. This is the unsurprising message — endlessly repeated — in this first volume of a report prepared by the Congressional Research Service (CRS) for use by the United States Senate Committee on Commerce, Science, and Transportation. Volume Two on "Soviet Manned Space Activities and Supporting Life Sciences Research" and Volume 3 on "Soviet Unmanned Space Programs, Including Space Sciences, Applications, and Military Activities" are yet to be published.

The first chapter of this long and detailed paperback is titled "Supporting Vehicles and Launch Vehicles." It was written by the late Charles S. Sheldon II, the CRS's expert on space flight and widely regarded as one of the world's foremost experts on the Soviet space program, and by Geoffrey E. Perry, a teacher at the Kettering Boys' School in England. Perry's "Kettering Group," which started as a class project, continues to listen to and interpret Soviet space telemetry. They were the first to publicly discover the Soviet Union's military space port at Plesetsk and pinpoint its real location.

This semi-technical first chapter presents detailed statistics on the numbers and kinds of flights the Soviets have attempted. It introduces their three main launch sites at Tyuratam, Plesetsk, and Kapustin Yar, and describes the facilities available and the blatant lies the Soviets have told regarding their locations. For example, in discussing Tyuratam, the authors write: "To this day the Russians pinpoint the launch pad for manned flights as being at 47.3° N and 65.5° E [near the town of Baikonur, which is what the Soviets call the launch site], which is patently false in light of conclusive public evidence of initial revolution ground traces and known launch times."

Unfortunately, although this chapter is likely to be the most interesting to ASTRONOMY's readers — and is certainly the best written and researched — it is also likely to prove the least useful. The material was obtained not from some intelligence agency's work but from readily available public sources. (The most commonly cited source is the British Interplanetary Society, and members will find little here they do not already know.) Nonetheless, the chapter gathers together a vast amount of information.

Chapter Two, "The Political Goals and Purposes of the USSR in Space," is by Joseph G. Whelan, the CRS's senior specialist in international affairs. This is where the book begins to get difficult: the reader is presented with a lot of information on international politics little of which appears directly related to space flight. Whelan outlines his views on the roots of superpower rivalry, then condenses them to the "distrust and fear" encouraged by radically differing world views.

What does all this have to do with space flight? Whelan concludes that east/west rivalry is the single most important force shaping the advancement of space flight today. He sees a growing complexity of the international environment that reduces the ability of the superpowers to assert their will, the decline of detente that presages the possibility of Cold War II and an emerging maturity in the Soviet management of space politics, in that they no longer allow political goals to interfere directly with the conduct of individual missions.

Whelan sees little hope for cooperation on major projects in the near future. He believes space flight, in general, will continue to be a political tool used to demonstrate technological and social prowess to the Third World.

Whelan also wrote the third chapter, "Soviet Attitudes Toward International Cooperation in Space." Here he describes the political, economic, and physical forces which encourage cooperation, and shows that the Soviets are committed to cooperative space programs, although with a very limited number of partners and only for clearly defined geopolitical purposes.

Francis T. Miko, CRS specialist in Soviet affairs, wrote the chapter "Administration of the Soviet Space Program," half of which explains the Soviet political system. Since this is a subject most Americans know nothing about, it is highly recommended for anyone who wants to better understand the Russian space program.

John P. Hardt, CRS senior specialist in Soviet economics, and George D. Holliday, specialist in international trade and finance, discuss the "Resource Burden of the Soviet Space Program." They present another extensive, yet important, discussion of Soviet politics supported by quotes from Soviet and United States experts. The authors then turn to what they call "opportunity costs" — the price that space expenditures extract in technological and social resources that could be used for other programs.

In these terms, the Soviet space program must be very expensive indeed: "The incremental burden of defense procurement on the machine-building and metalworking industries would rise from a level of 35 percent during the current Five Year Plan to 54 percent during the Twelfth Five Year Plan, if the past trend in defense spending growth continues." The authors conclude that "If Soviet space and military programs are to be slowed down, one might expect the military space share to retain or expand its portion compared to the civilian space programs, as this has been the case in the past."

Finally, the reader is presented with 50 pages of direct quotes from Soviet officials and cosmonauts concerning their future in space, followed by a listing of Soviet launches.

It should be clear by now that this book is not an "easy read," nor is it meant to be. It presents far too much detail and covers too much ground not directly related to the subject at hand. But nowhere else can you find such a complete overview of Soviet space exploitation and, more importantly, the reasons behind it. *Donald Robertson.*

Check a Possible Supernova

Juhani Salmi
42 pages, wire-bound, 29 Finnmarks (about $5)
Published by the author (1984)

This is an age of large deep-sky telescopes and observing distant galaxies in detail. Lurking in some of these far-flung islands of light are the exploding stars known as supernovae. Important to astrophysicists, supernovae are now being discovered by amateurs who search galaxies visually, looking for new stars that "don't quite belong." Juhani Salmi's book contains index card-size photographs of 40 galaxies and the surrounding fields which observers can compare with what they see in their eyepieces. Designed expressly for supernova searchers, it is compact and convenient.

The 40 negative prints (black stars on a white sky) include a variety of galaxies visible to northern hemisphere observers. They include the southern half of M-31 (why not the northern half?), all of M-33, and several more Messier galaxies followed by some fainter NGC objects. The Messier objects, arranged in numerical order, are followed by those from the NGC — also numbered sequentially so that a cold and tired observer can find the galaxy he wants quickly and easily.

Some of the photos are outstanding and provide excellent examples of what to look for. M-51 is easy to find and has a challenging, but not overwhelming, number of foreground stars and distant galactic clumps; a searcher must learn to recognize and then ignore them to prevent false alarms. M-63 is another good object, although the high contrast of its photograph introduces some false "supernovae" within the nebulosity that invite confusion. The Black-Eye Galaxy, M-64, follows in a photograph that does justice to its very dense nucleus. Unfortunately, the galaxy's density of stars makes it difficult for amateur supernova searches.

One problem with the book is the choice of galaxies. Most supernovae — about 66% — occur in mid- and late-type spirals (Sb through Scd on the Hubble system). Many of these are included, such as M-33, M-51, M-101, and NGC-6946, but Salmi also includes some lenticulars and early-type spirals, which are comparatively "supernova-free."

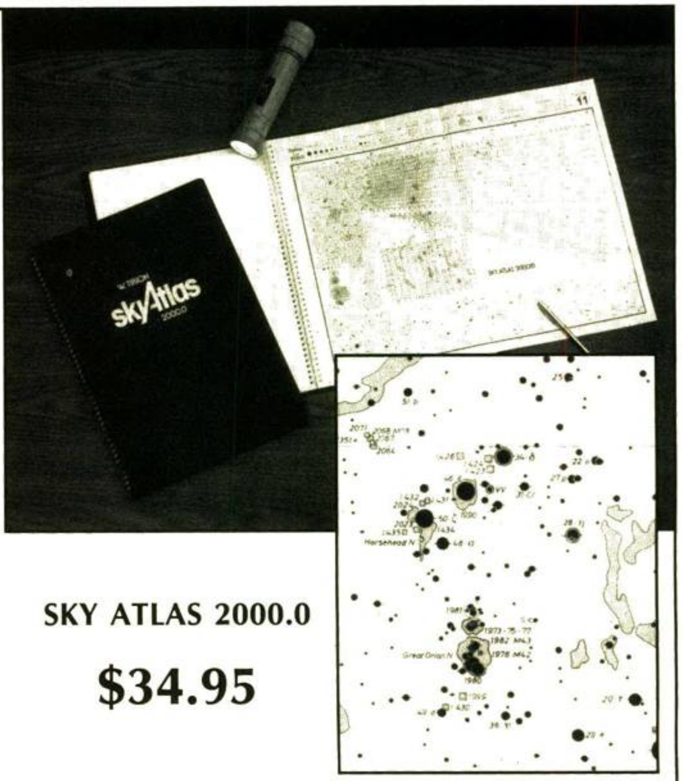
Although slight trailing occurs in one or two of the photos and the contrast in the printing is a little higher than I would have liked, the photographs themselves are generally excellent. I wish the book included data about the scale of the photographs (which is not constant from one to the next); this is especially notable in the photographs of M-81 and M-82. But these difficulties are minor when we look at the enormous potential of this unique collection of cards that may some day lead to the fame and thrill of a supernova discovery.

Lastly, the book has a value quite apart from its intended use. It's a marvelous pocket collection of some of the handsomest galaxies we have in our corner of the universe. Flipping though the pages impresses on you the realization that the diversity of galaxies is as great as that found in other parts of nature. The different combinations of gravity, size, and internal composition make each galaxy unique — and Salmi's book is a nice and inexpensive way to appreciate that often forgotten fact. *David H. Levy*

The Story of Astronomy in Edinburgh

Hermann A. Bruck
151 pages, hardcover, £8.50
Edinburgh University Press (1983)

This work, a historical treatise on astronomy and astronomers associated with Edinburgh, grew out of a paper the author presented at the 150th anniversary



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of the Royal Observatory in 1972. He details the early history of the university (founded in 1583 as Town's College), and discusses several significant people: Robert Blair, who in 1785 became the first professor of astronomy at Edinburgh; Thomas Henderson, Scotland's first Astronomer Royal; Charles Piazzi Smyth, son of the great observer Admiral William Smyth (who was a noted astronomer in his own right); Frank Dyson an astrometrist; and Ralph Sampson, who worked extensively on timekeeping.

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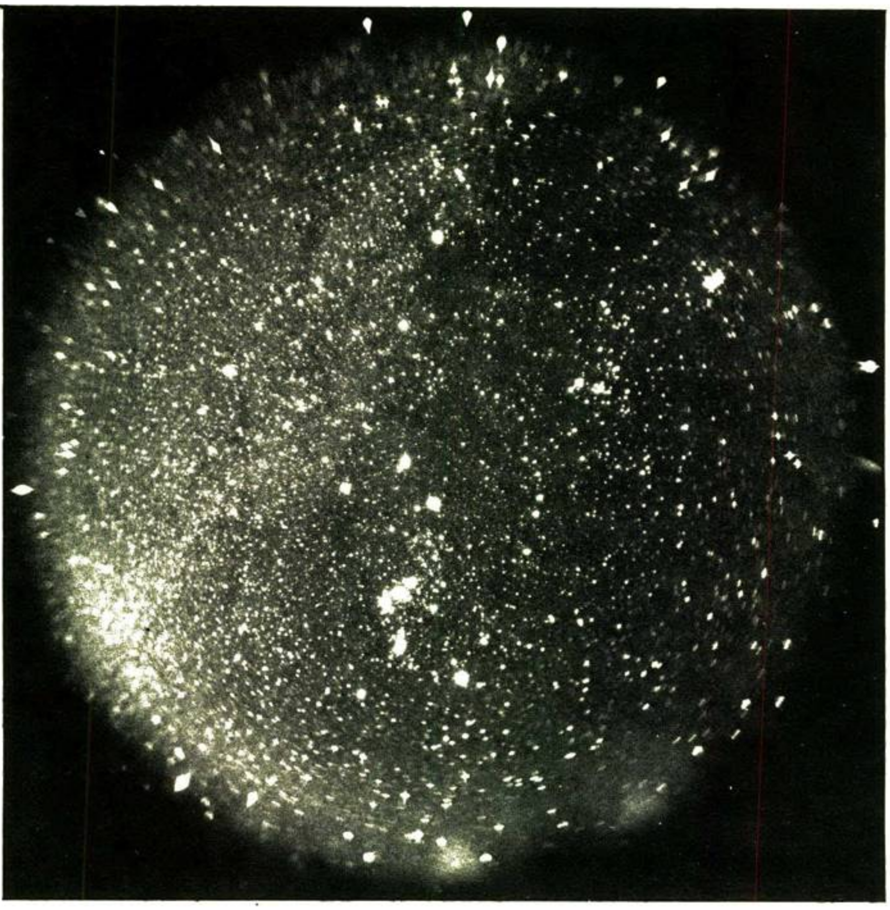
Eye on the Sky

Inner Planets at Their Best

by Fred Schaaf



Right: On January 28, 1984 the Moon lay near Jupiter and Venus in the morning sky. Photo by Peggy Stevens (no photo data available). Above: Turning an old 5x50 Moonwatch telescope around and photographing into the objective, Gordon Solberg made this 15-minute exposure on Tri-X to obtain a wide-field view of Orion, Taurus, Auriga, and the adjoining band of Milky Way.

The Wanderers

This is the year that Halley's Comet becomes visible in small telescopes and binoculars — and by December, to the naked eye. Of course, even the largest backyard telescopes will probably not show Halley until August. But it's still exciting to know that on January 10, Comet Halley crosses Jupiter's orbit, inbound for perihelion.

The year of Halley's return begins with all the planets gathered on the same side of the sky as the Sun. Fortunately, not all the planets lie too close to the Sun for good viewing. In fact, both Venus and Mercury achieve their greatest angular separations from the solar glare and are unusually prominent this month.

Venus, having lain low during much of 1984, finally climbs high into the evening sky and gains 10° of elevation during January. The planet is slightly brighter than −4.0 magnitude and will brighten more all month as it swings toward Earth. On January 22nd, our line of sight to Venus becomes tangent to its orbit. This is when Venus reaches greatest elongation — its angular separation from the Sun will then be 47°.

For observers at mid-northern latitudes, the ecliptic's angle to the horizon is more important than elongation. In the case of Venus, the angle is relatively steep now and will become even steeper as we approach the vernal equinox. Early next month, Venus will have an even higher altitude than it does now at greatest elongation. Also note how much farther north the planet appears each week.

Besides increasing in altitude and brightness, Venus is also slowly closing in on first-magnitude **Mars**. As the year begins, Venus lies only some 10° west of Mars in Aquarius — the two will remain within 10° of each other for the next 2½ months! Even more amazing, they will be within 5° of each other for a month and a half. By the end of January, the gap between Venus and Mars will shrink to only a few degrees and a conjunction in right ascension will seem imminent. But the planets' motions are so closely matched that conjunction does not occur until February 8th.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

While Venus is attaining greatest elongation in the evening sky, **Mercury** does the same in the eastern sky at dawn. Mercury rises just before the start of morning twilight as 1985 opens, with greatest elongation (23°) taking place on January 3rd. (Coincidentally, this is the same day **Earth** is at perihelion.) Look for it from somewhere with a low horizon to the east. Although Mercury remains relatively bright, by mid-January its altitude and visibility will rapidly diminish. By January 31st, when Mercury passes just over 1° south of Jupiter, there is little hope of seeing the planet itself with the naked eye. **Jupiter** itself is in conjunction with the Sun on January 14th and will be out of view essentially all month.

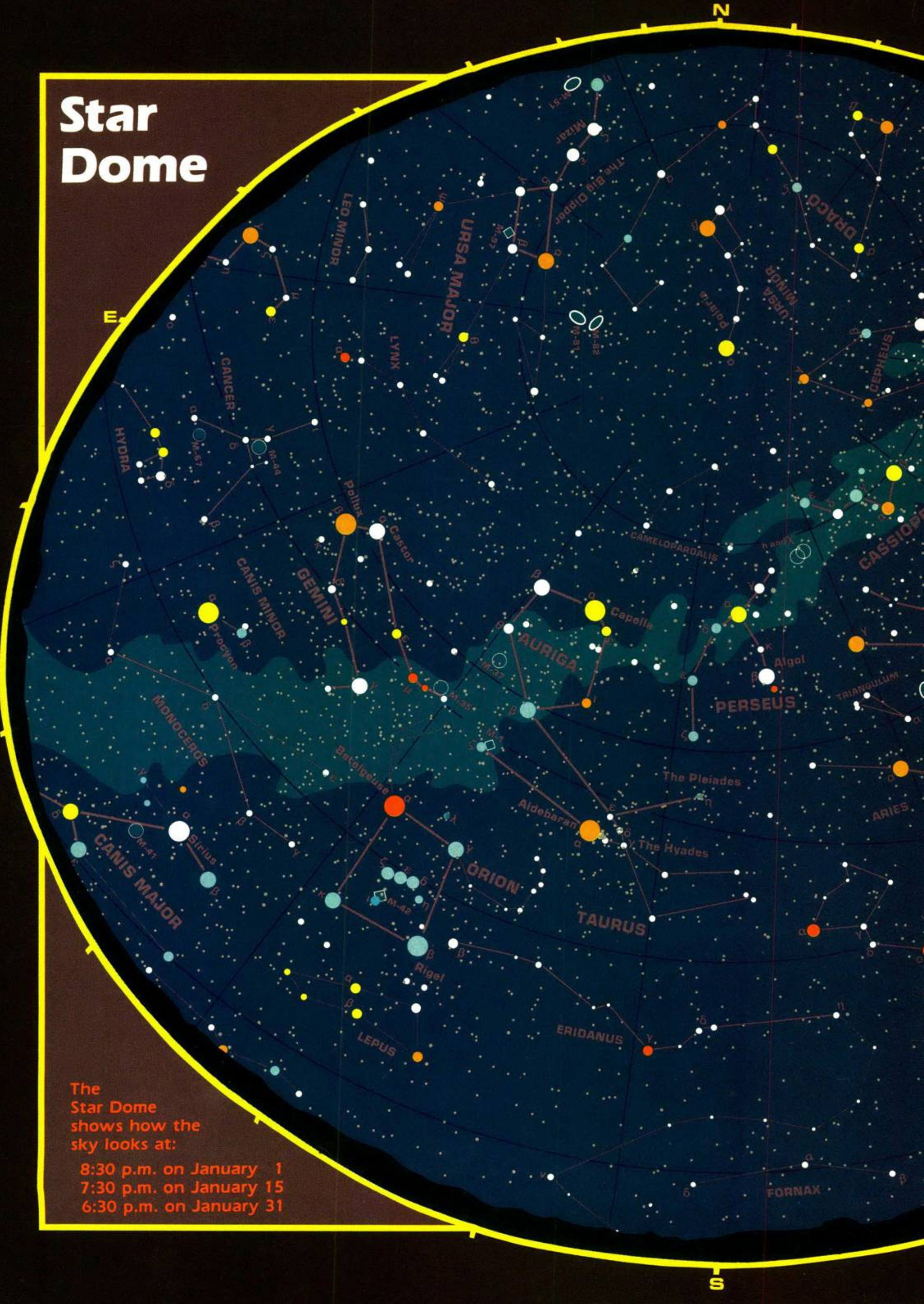
While Mercury lingers in dawn murk, **Saturn** is higher up and shining in the southeastern sky. Although at its minimum magnitude for 1985 (0.6), Saturn nevertheless appears bright for lack of nearby stellar competition. Now in eastern Libra, Saturn will move toward the head of Scorpius during the next few months but will begin retrograde motion before reaching it. Saturn passes only 10 arc-minutes south of fifth-magnitude Zeta (ζ) Librae on the evening of January 1st, but you'll need to use binoculars at least for observing the star.

The last solar system event of note this month is the **Quadrantid meteor shower**. The number of meteors you can observe during the night depends on when this shower's brief peak of activity occurs in your part of the world. Unlike last year's display — well-timed for North Americans — this year's Quads will provide generally a poor view for most observers: at a dark site, you'll see no more than a dozen or two meteors during the few hours between moonset and morning twilight on January 3rd and 4th. The shower's radiant lies northeast of Bootes.

The Starry Sky

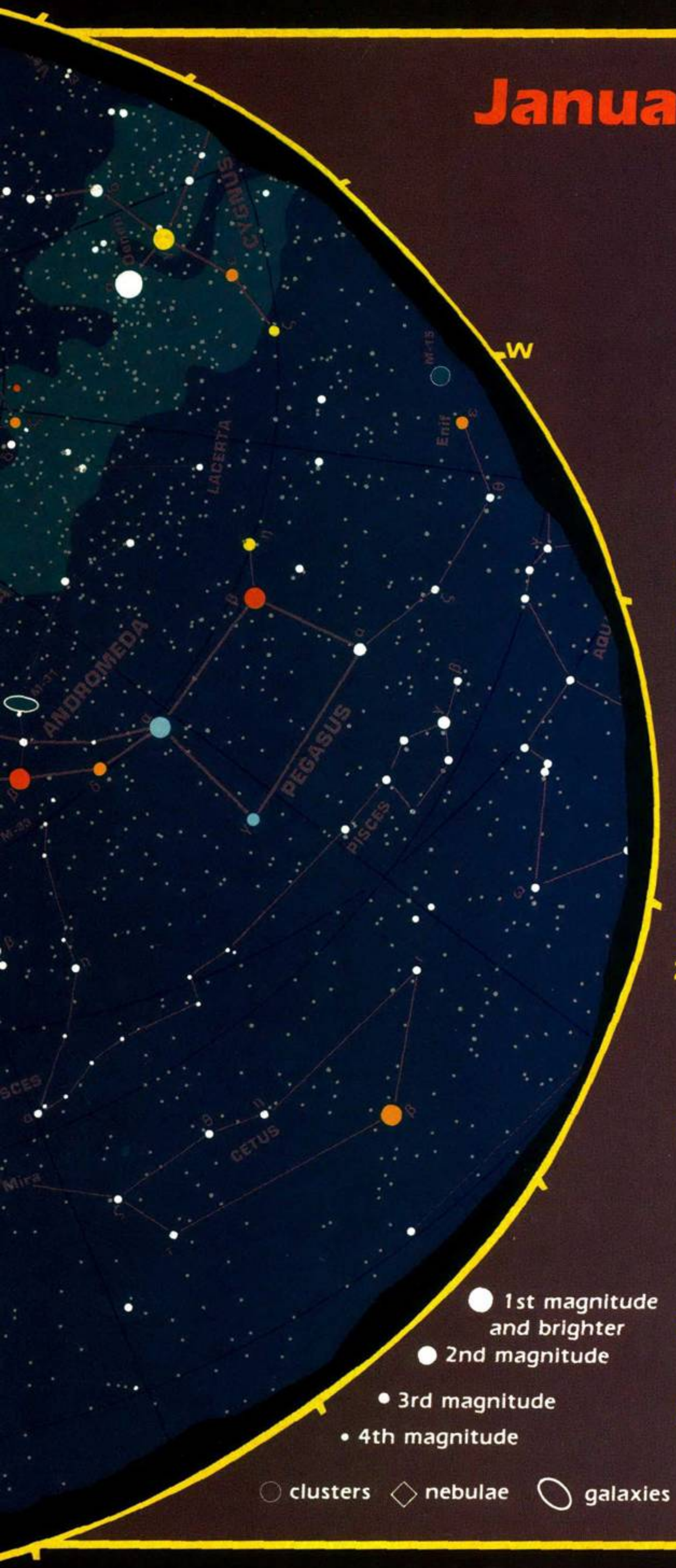
No constellation is such a center of attention as **Orion** the Hunter. Many of

Star Dome


N
E
S
M-51
Mizar
The Big Dipper
LEO MINOR
URSA MAJOR
M-97
DRACO
URSA MINOR
Polaris
M-81
M-82
LYNX
CEPHEUS
CANCER
HYDRA
M-67
M-44
Pollux
Castor
GEMINI
CANIS MINOR
CAMELOPARDALIS
CASSIOP
Capella
AURIGA
Procyon
M-37
M-35
Algol
PERSEUS
TRIANGULUM
MONOCEROS
M-1
Betelgeuse
The Pleiades
ARIES
Aldebaran
The Hyades
CANIS MAJOR
M-41
Sirius
ORION
M-42
TAURUS
Rigel
LEPUS
ERIDANUS
FORNAX

The Star Dome shows how the sky looks at:

8:30 p.m. on January 1
7:30 p.m. on January 15
6:30 p.m. on January 31


CYGNUS
Deneb
M-15
W
Enif
LACERTA
ANDROMEDA
M-31
AQU
PEGASUS
PISCES
M-33
SCES
CETUS
Mira
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

January Sky Almanac

1st Mercury is visible low in the eastern sky during the hour before sunrise.

3rd Mercury is at greatest western elongation, 23° away from the Sun. Also: Earth is at its closest to the Sun.

6th Full Moon occurs at 9:16 p.m. EST.

11th The Moon is closest to Earth at 10:26 p.m. EST: 229,653 miles.

13th Last Quarter Moon arrives at 6:27 p.m. EST.

14th Jupiter is in conjunction with the Sun; it switches from the evening to the morning sky. By the end of January, you may be able to glimpse it very low in the east-southeast just before sunrise.

16th A waning crescent Moon lies a few degrees east of Saturn when they both rise this morning.

20th New Moon is at 9:28 p.m. EST.

22nd Venus reaches greatest eastern elongation, 47° away from the Sun. The planet, now at −4.4 magnitude, will climb higher each day in the evening sky.

24th The crescent Moon will pass to the south of Venus, missing it by about 5°. A few hours later, it will pass south of Mars, missing it by about 4°. (This is a good opportunity to see for yourself that the Moon really does move!)

27th The Moon is farthest from Earth at 4:32 a.m. EST: 251,432 miles.

28th First Quarter Moon occurs at 10:29 p.m. EST.

winter's star patterns could equal or surpass the best found in other seasons, but on winter nights when Orion is in their midst, they give way and gather around him like his court.

Orion doubly surpasses the Big Dipper, with its two first-magnitude stars as well as a prominent pattern of second-magnitude stars. Actually, one of the first magnitude stars, blue-white Rigel in Orion's lower right corner, is much closer to zero magnitude. The other, ruddy-orange Betelgeuse at Orion's upper left, varies slightly in brightness — but only about 0.5 to 0.7 magnitude.

Halfway between these stars is a striking asterism, the Belt of Orion. The line of his belt is formed by three second-magnitude stars called (from northwest to southeast) Mintaka, Alnilam, and Alnitak. Completing the main figure of the Hunter are Bellatrix (to the right of Betelgeuse and marking his western shoulder) and Saiph (below Betelgeuse and marking his eastern knee). Bellatrix and Saiph are also second-magnitude suns.

Not all backyard astronomers know how to trace the shield of Orion (which lies to the west of Bellatrix) or his club (to the northeast of Betelgeuse), since these are both formed from dim stars and are difficult to see under typical urban or suburban skies. But every astronomer should know the Sword of Orion. This is a short line of stars running roughly north-south just below Orion's Belt. This is where we find our brightest and most spectacular nebula M-42 — the great Orion Nebula — a cloud of luminous hydrogen gas that enwreathes the multiple star Theta (θ) Orionis. If Theta did not interfere with the naked-eye view, you'd easily see the nebula itself without optical aid. As it is, get your binoculars or a small telescope and use its lowest magnification. Looking at Theta in the middle of the Sword, you'll see the glow of the nebula, which photographs show extends across more than one degree of sky. For many amateur astronomers, the Orion Nebula wins the title of most spectacular deep-sky object.

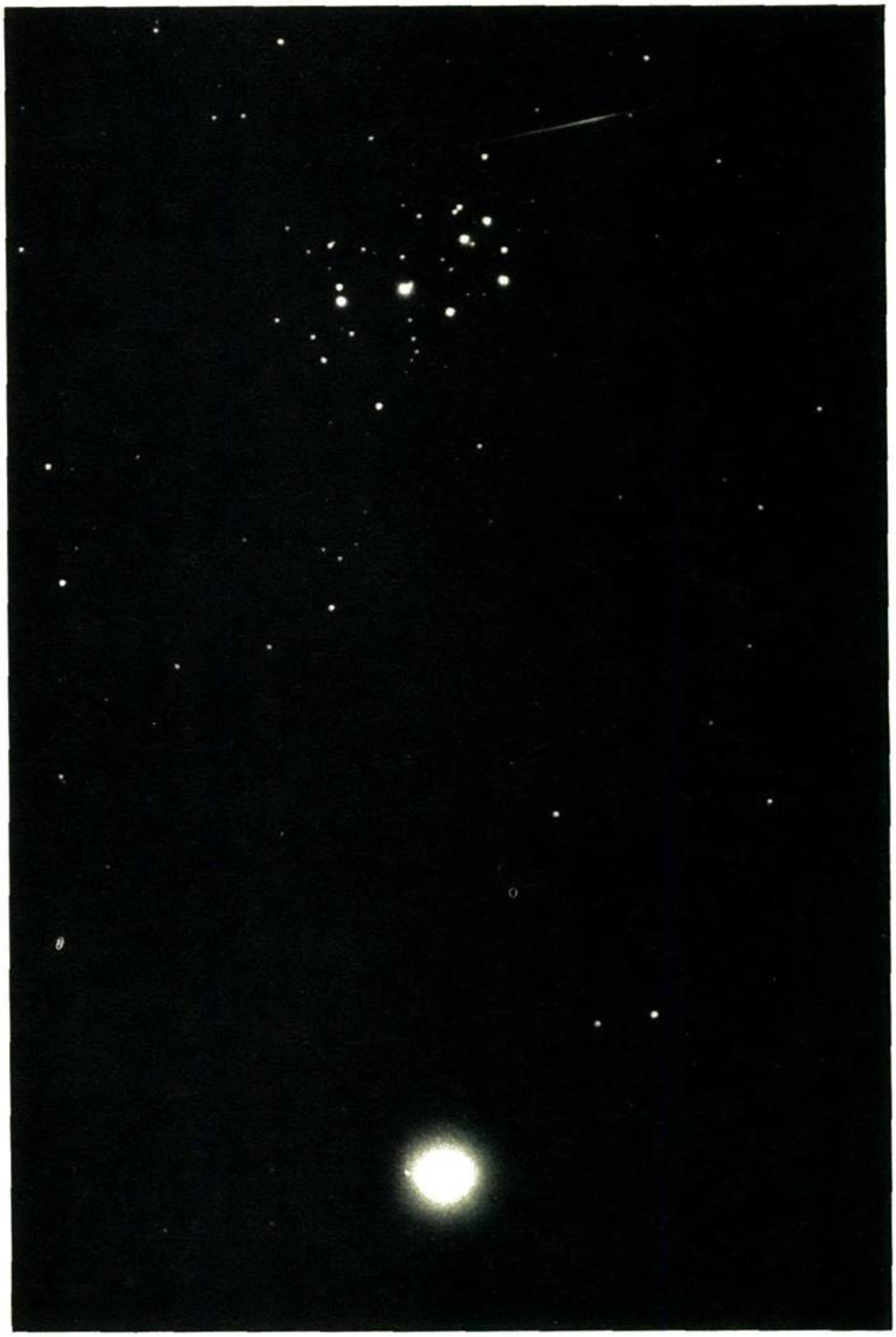
Let's now shift to a part of Orion that's often neglected: the Hunter's head. This is formed by a very compact triad of stars. The brightest of these is Lambda (λ) Orionis, also known as Meissa. People who find it hard to believe the Moon can fit within the bowl of the Pleiades will be even more surprised to know the lunar disk could also be placed within this tiny triangle! Orion's head takes on special interest this month because Comet Halley — still much too faint to be observed in all but large professional telescopes — drifts only 1.1° north of Meissa on January 13th.

If you extend the line of Orion's Belt in either direction, you'll find a bright star at the same distance from it. Twenty degrees to the northwest brings us to first-magnitude Aldebaran, the brightest star of **Taurus** the Bull. Last month, we examined the two great Taurus clusters — the Hyades and the Pleiades — in considerable detail. But Taurus holds more attractions than these. The tips of Taurus' horns are indicated by the stars Beta (β) and Zeta (ζ) Tauri.

Zeta is the fainter and has no common name used in modern times, yet observation and research have revealed an object near it which lends this star special importance. Just northwest of Zeta lies M-1, also known as the Crab Nebula; this is the first object which French comet-hunter Charles Messier put on his list of "comets-that-aren't." The Crab is almost certainly the youngest object in Messier's list: whereas most astronomical objects are at least millions of years old, the Crab Nebula is much younger. The nebula is the cloud of gas ejected by a supernova which flamed brighter than Venus in the year 1054. However, today's Crab Nebula is dim enough to require a telescope for viewing.

Taurus' other horn-tip is marked by the star Beta Tauri, often called El Nath. Like Alpha Andromedae in the fall sky, El Nath helps form the patterns of two constellations — although officially, it belongs only to one: El Nath completes the pentagon of **Auriga** the Charioteer.

Auriga is known for its yellowish zero-magnitude luminary Capella — meaning "she-goat" — but also has several good *open star clusters for binocular observing.* One of them, M-37, can be seen with the naked eye in very dark skies. Other stars of interest include the three Kids (baby



Left: Canis Major was rising in the southeast when Henry Nebel made this photograph using a 50mm f/2 lens and 5-minute exposure on Ektachrome 400 pushed to ISO 800. Right: An Orionid meteor streaks past the Pleiades with Jupiter to the south. This photo was taken in October 1976 by Seth Horowitz, who used a 135mm f/2.8 lens and a guided 23-second exposure on Tri-X.

goats, that is!) just a few degrees southwest of Capella. The northeast side of the pentagon, the line from Beta to Theta Aurigae, closely follows the 6h line of right ascension; you can even use this line to locate Polaris in **Ursa Minor**, the Little Bear. (The North Star lies about 45° from Theta Aurigae.)

Going back to Orion's Belt, if you follow the line about 20° southeastward you'll come to glorious Sirius in **Canis Major**, the Greater Dog. Sirius is the brightest of all the stars in the terrestrial sky and, along with Procyon and Gemini twins Pollux and Castor, will be among our topics next month.

Skylore

In our fascination with Orion, Taurus, and Auriga, we have ignored a few fainter winter constellations. One of these is Lepus the Hare. Lepus contains two second-magnitude and six third-magnitude stars. Perhaps it's only the proximity of magnificent Orion which has demoted Lepus to relative obscurity. Be that as it may, there's not a tremendous amount of lore concerning Lepus — unless we leap to some very puzzling worldwide legends concerning the lunar hare.

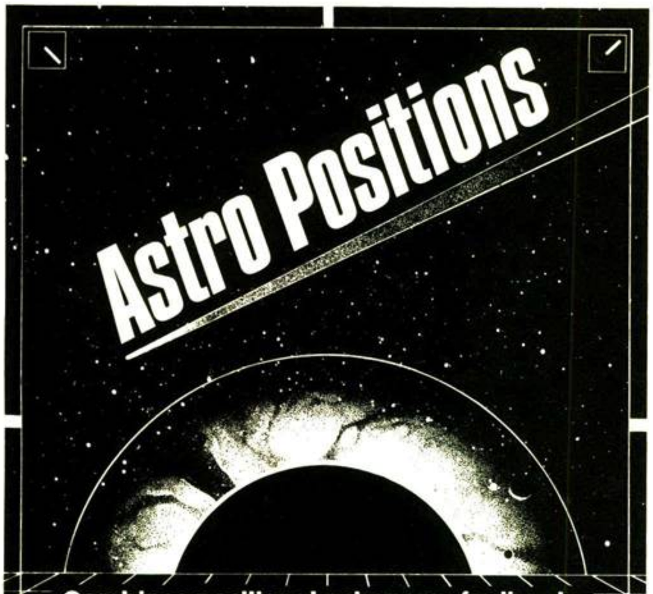
But first, we should note that Lepus was known in his present form as far back as the ancient Greeks. Like us, the Greeks made a natural association between the celestial Hare and Hunter; also like us, they probably thought the hare was an altogether unfitting quarry for so mighty a hunter.

Many centuries later, the Arabs followed the Greeks by naming Lepus as Al Arnab ("the hare"); this influence remains with us today in the name Arneb — the brightest star in the constellation Alpha Leporis. An Arab name for the four brightest stars of Lepus was Al Nihal, "the thirst-slaking camels." R.H. Allen (in his book *Star Names*) thinks this refers to the nearby celestial stream of the Milky Way. In the *Astronomical Companion*, Guy Ottewell writes that *an-Nihal* means "the camels" (of one particular kind) and adds that "the Arabs have ninety-nine names for God, a hundred words for the lion, and a thousand words for the camel." In any case, Nihal is now the name for Beta Leporis — the 2.8 magnitude star close to Arneb.

According to R.H. Allen, the early Arabs recognized the four brightest stars of Lepus as the Chair of the Giant or the Throne of the Jauzah — that is, the Chair or Throne of Orion. The Chinese imagined Tsih, a sled, in the stars of Lepus. J.F. Jewitt claimed that for the early Egyptians, Lepus was the boat of their great god Osiris who himself was identified with Orion. On the other hand, the famous Denderah zodiac (or planisphere), which some scholars claim shows the Egyptian constellations of 700 B.C. or earlier, replaces Lepus with a serpent being attacked by some bird of prey.

The eagle and other birds of prey are notorious enemies of the hare. Perhaps the fact that Lepus rises only when Aquila the Eagle is setting (as seen from mid-northern latitudes) was noticed by the ancient Greeks. The antagonism between hares and crows or ravens was apparently a matter of legend long before Aelian mentioned it in the 2nd century AD. It was said that the hare detested the voice of the raven — understandable enough! D'Arcy Wentworth Thompson, a British ornithologist who studied the lore of celestial birds, suggested the source of this legend was astronomical: Lepus is sinking low in the southwest as Corvus the Crow rises in the southeast.

So much for the connections of Lepus with other constellations — what about its involvement with the Moon? Actually, we can't say that the *constellation* Lepus has been associated with the Moon — only that the creature which Lepus represents has lunar connections. But why hares or rabbits should be related to the Moon, in stories from dozens of ancient cultures far-separated in space and time, remains a great mystery. Our next Skylore will look at some of these legends and speculate on what people might have made of those curious markings on the face of Earth's natural satellite.



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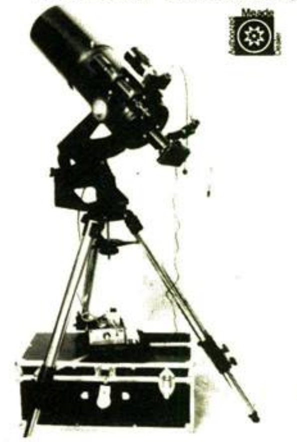

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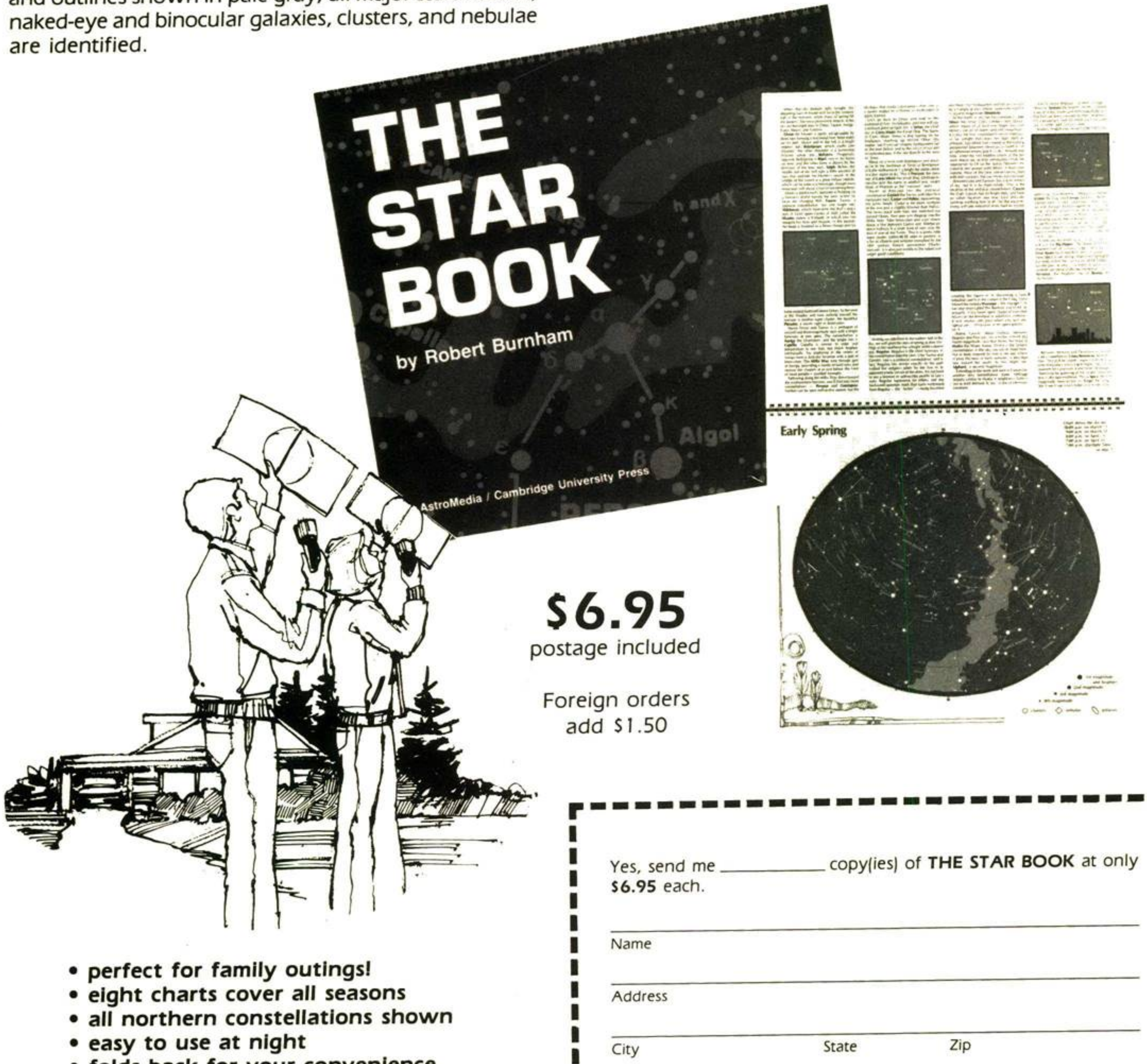

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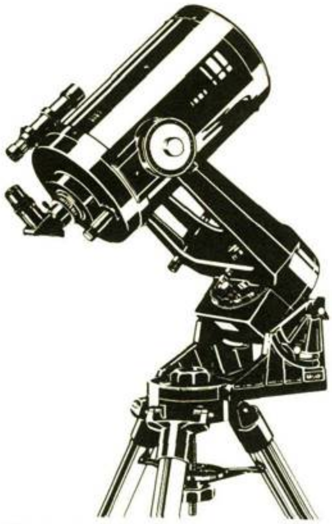

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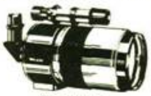

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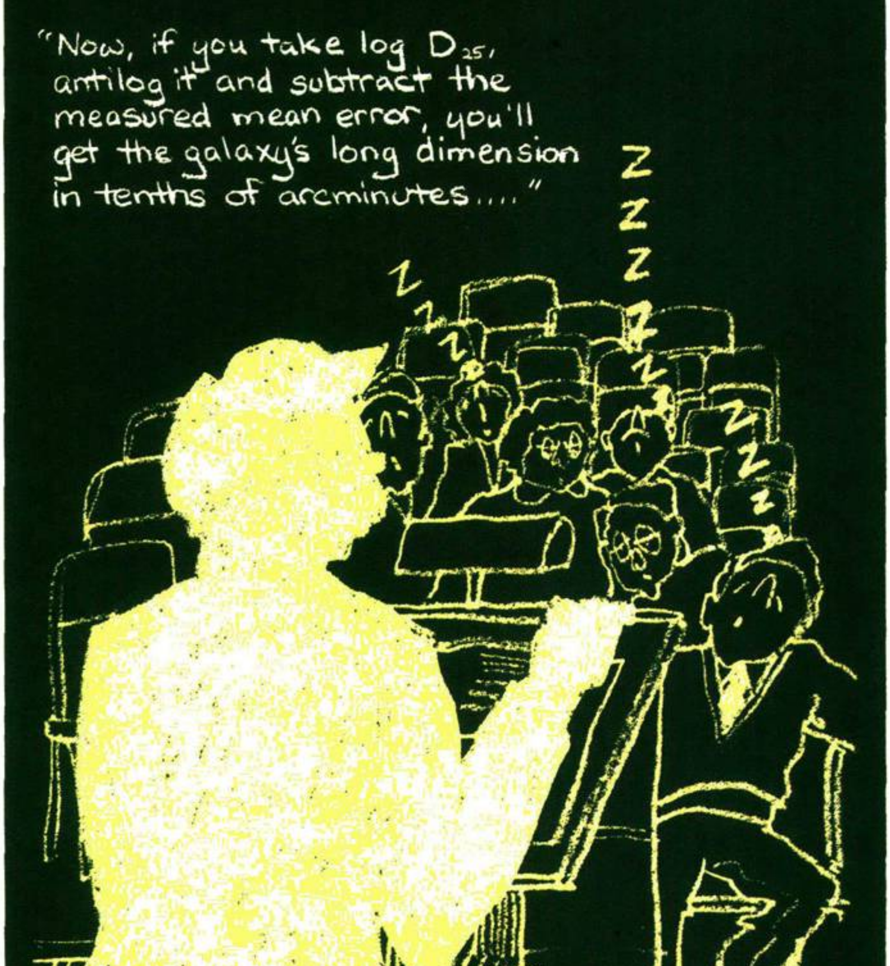
How to Revive a Tired Astronomy Club

by Art and Helen Sweeny


"Now, if you take log D_{25}, antilog it and subtract the measured mean error, you'll get the galaxy's long dimension in tenths of arcminutes...."
Z Z Z

Are your club meetings a bore? Do members tend to nod off during the talks? Do your speakers have to shout to be heard over the snores? If so, it may be time to stop and think about how your club operates, what it offers to the members, and why it functions as it does. Periodic slumps of activity and enthusiasm occur in every astronomy club, but members don't always take the best course of action to smooth them out. Here are a few suggestions to get a tired astronomy club back on its feet.

First Comes First: The Monthly Meeting

The first step in motivating club members is to catch their interest. Make those monthly meetings lively and entertaining. The ruin of many astronomical societies is the routine showing of old, outdated NASA films while everyone valiantly tries to stay awake until the last reel has whirred its way through the projector. It's easy to put together a bad club meeting, but difficult to organize one where everyone learns something — especially the guys who have been members since 1928.

A good start is presenting "show and tell" talks by club members. Try to involve everyone — from teenage students who took their first astrophoto last week to semi-professionals who go out and estimate variable stars all night long. The show-and-tell approach is usually a good icebreaker and leads to informal discussions on all types of astronomical subjects.

Astrophotography is a nearly ideal show-and-tell subject. It provides technical information for prospective collectors of starlight but is also aesthetically interesting to those who couldn't care less what your f/ratio is. A program on simple, unguided, constellation photography — showing how to mount a loaded camera on a tripod, point it at a constellation, and expose it for 30 seconds — can spark a lasting interest in astrophotography. You can also show photographs (taken of an object like M-42, for example) using different methods — cold camera, hypersensitized film, VR1000 and other super-speed emulsions, and straight shots on normal films. Even Polaroid films do well for constellation photography. If there is enough participation, you can hold a club astrophotography contest.

Another good show-and-tell subject deals with testing and evaluating telescopes. This will ensure that members know the characteristics of their own telescopes, know how to correct problems when they're out under the stars, and understand how to maintain and protect their equipment investment. Everyone in the group should at least learn how to properly align their scope's optics. You should also know how to star-test an image when you're out under the stars. It's relatively simple (see "How to Star-Test Your Telescope," ASTRONOMY, April 1983).

How many of your club's members know what's up in the sky at any given time? You can bet that every newcomer will appreciate a "tour" of the basics. Plan an observing program by projecting star maps, sketches, or photographs of objects. Cover the bright "main attractions" for the beginners and include more exotic game for advanced observers. Don't forget to explain how to read a star map — remember how confused you were at first!

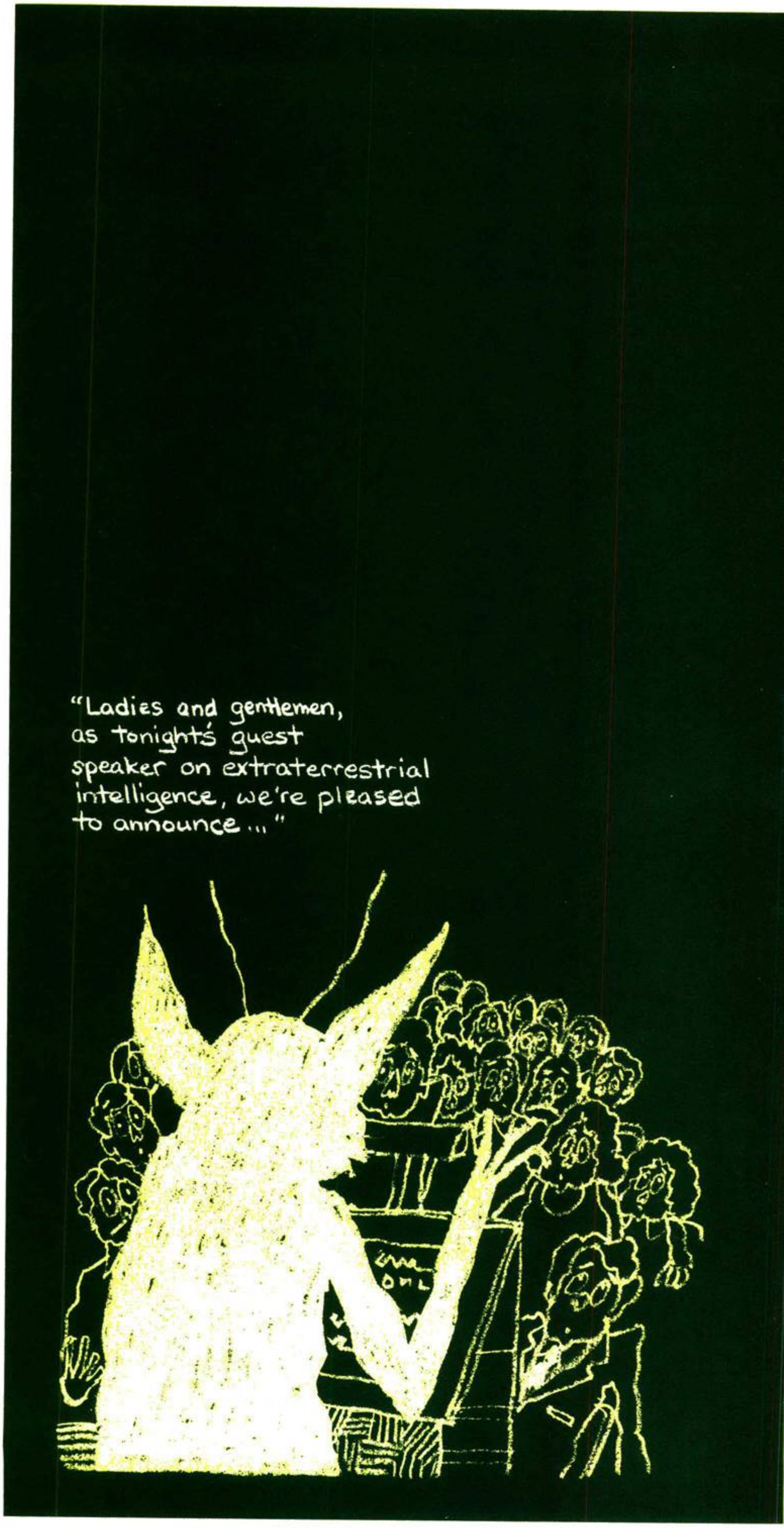
The Search for Guest Speakers

Guest speakers don't have to be experts from outside the club — start with the club's most ambitious members. An occasional outside guest can generate interest and renew enthusiasm, but members themselves are often experts on many, varied subjects.

The Texas Star Party, held every spring in the Davis Mountains of Western Texas, is one of the country's largest and best gatherings of amateur astronomers. We found it a marvelous place to find topics for programs. The following are some that we heard about at the 1984 Texas Star Party.

A ranger who worked near Mount St. Helens, Washington, described the eruption and problems caused by the volcano in 1982.

A college biology professor outlined the conditions necessary for life in the universe and speculated on the probability


"Ladies and gentlemen, as tonight's guest speaker on extraterrestrial intelligence, we're pleased to announce ..."

of its existence elsewhere.

The advantages and liabilities of certain types of telescopes were outlined by an observer. Demonstrations and clearly illustrated diagrams were included.

A modern-day astrologer explained his profession and how it is applied in today's world. (This is a good program for April.)

The list goes on and on, but the point is that many topics related to astronomy are just as interesting as more traditional approaches (see box at left).

Finding Club Projects

In addition to interesting meetings, a club project is a good way to get people involved and keep them motivated. A good first step is organizing regular public star parties — at least one every two months. This adds to your observing time, shows non-astronomers some of the sky's sights, and attracts new members. They can be held at dark-sky sites but it is more convenient to hold them at well-known, easy to find locations. If the Moon and a few planets are up, you can start by looking at craters on the Moon, the rings of Saturn, Jupiter's belts, or features on Mars (see "Planning a Star Party?", ASTRONOMY, October 1984). Distribute some simple star maps and announce upcoming club meetings. Explain the different types of telescopes, how they work, and their merits and disadvantages. People interested in buying a telescope will appreciate this and may become active club supporters.

A club star party at a dark-sky site which focuses on topics for more experienced members can be held whenever weather and members' schedules cooperate. Many clubs hold stargazes on Friday nights when everyone can stay up late for observing and astrophotography. If the weather turns bad on the scheduled Friday, Saturday night can serve as a backup.

Another club project includes teaching a course in elementary astronomy to the community. This will interest not only club members, but the general public and science teachers as well. In some areas, the teachers can receive "in-service training" credits for attending such a course — some may even help teach it.

Subjects for Program Meetings

Astrology and Pseudoscience
Black Holes
Comets and Meteors
Computers in Astronomy
Deep-Sky Observing and Photography
Distance Scale of the Universe
Eclipses for the Coming Decade
Elementary Physics
Eyes and Observing
Extraterrestrial Life
Galaxy Dyamics
Geophysics
Greats in the History of Astronomy
Light Pollution
Mars and Percival Lowell
Observatory Hopping
Observing the Outer Planets
Philosophy of Science
Planetary Mechanics
Pulsars
Quasars
Relativity
Sunspots
Telescope Making
Time
UFOs
Venus and the "Ashen Light"

. . . and so on.
Try a little imagination—
it works
every time!

Publicity is the key: One club which organized such a course and promoted it heavily had 50 persons attend the first session and 250 the second! Be ready with arrangements for large meeting places in case this happens to you.

Telescope-making projects are also popular. You can organize a mirror-grinding project by buying kits (containing blanks, carborundum, and lap) in bulk, which are fairly inexpensive. Or you can offer a workshop where people can assemble scopes from ready-made parts. Participants can work independently or in a group. You can also run a joint project to make a club mirror and have everyone take turns with the grinding.

Observing projects are difficult to organize on a small scale, so you might investigate several of the national organizations involved with observing. The American Association of Variable Star Observers (AAVSO) is a clearinghouse for variable star observations. For planetary work, the Association of Lunar and Planetary Observers (ALPO) engages in monitoring planetary features, meteor showers, comets, and asteroids. The International Occultation Timing Association (IOTA) concentrates on recording occultations involving stars, planets, and the Moon. The National Deep Sky Observers Society (NDSOS) promotes observation and photography of clusters, nebulae, and galaxies, and has information about supernova searching and deep-sky data. See the box at right for addresses of these groups.

If your astronomy club has lost some of its gusto, don't worry — it's not necessarily fatal. There are many ways to revive an ailing group of observers and bring their enthusiasm back to life. Just by polishing up the meetings, you'll soon have a newly energized, skilled group of people working together again.

Art and Helen Sweeny have been interested in astronomy since 1944, when they joined the Astronomy Club of Tulsa, Oklahoma. Art is a past president of the club and serves on the board of directors. Helen is an armchair astronomer and freelance writer.

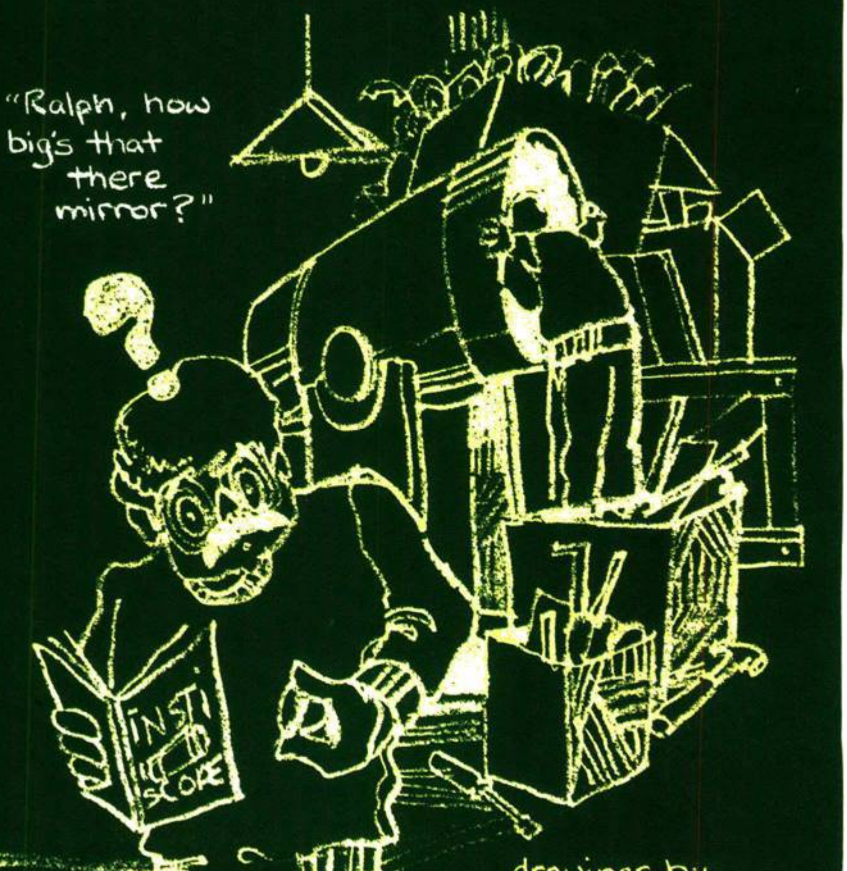
Addresses of Observing Groups

American Association of Variable Star Observers
187 Concord Avenue
Cambridge, MA 02138

Association of Lunar and Planetary Observers
Box 3AZ
University Park, NM 88003

International Occultation Timing Association
Box 3392
Columbus, OH 43210

National Deep Sky Observers Society
3430 Bryan Way
Louisville, KY 40220


"Ralph, how big's that there mirror?"
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drawings by
Barbara Ericksen

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(apparent field of view in parenthesis)

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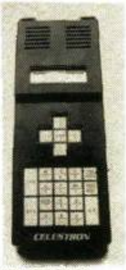

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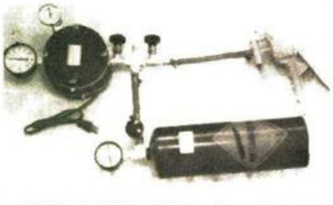

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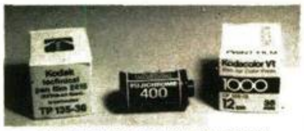

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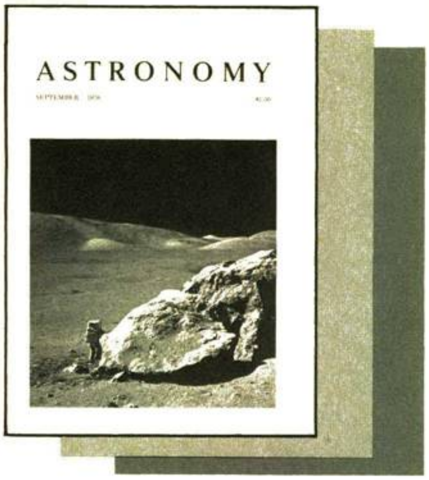

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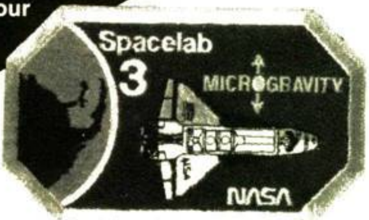
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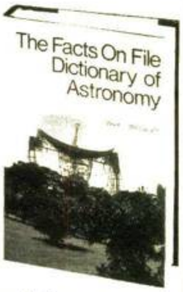
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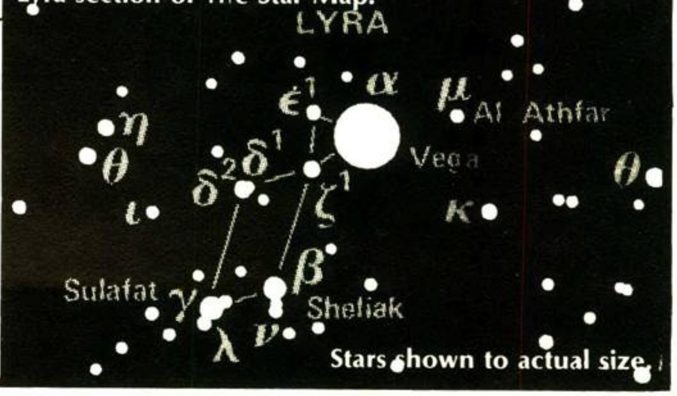
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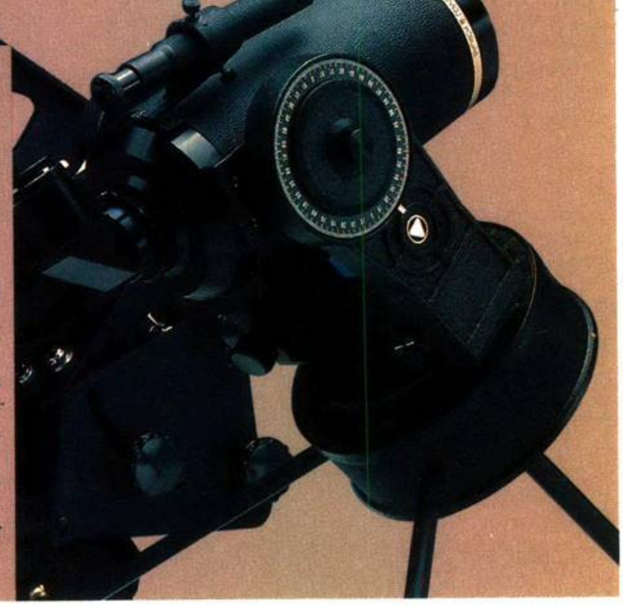

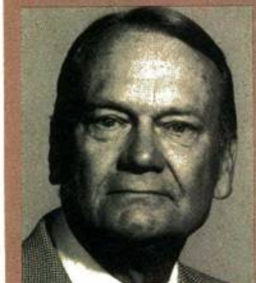

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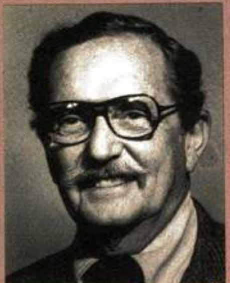

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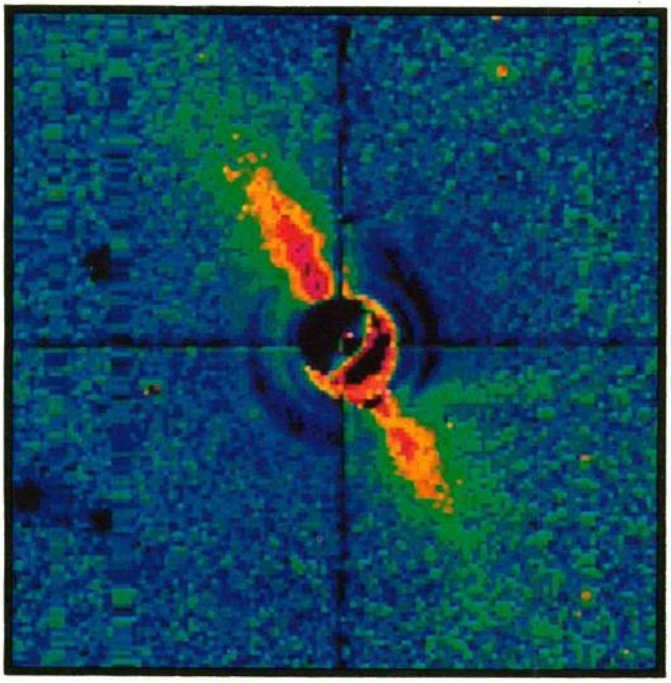
ASTRO NEWS



JPL/University of Arizona

Protoplanetary Nebula around Beta Pictoris

Beta Pictoris, a 3.9 magnitude type A star, lies at the center of a "protoplanetary" disk at least 800 astronomical units in diameter, according to astronomers at the University of Arizona and Jet Propulsion Lab. This discovery is the first detection at visible wavelengths of a "solar" nebula around a nearby star.

Beta Pictoris is one of four stars listed as unusual by astronomers using the IRAS orbiting infrared telescope. Other stars named were Alpha Lyrae (Vega), Alpha Piscis Australis (Fomalhaut) — see AstroNews, April 1984 — and Epsilon Eridani. Fomalhaut and Vega have surrounding dust and possibly planetary systems, but these have not been seen at optical wavelengths.

Because of the brightness of the star and faintness of the nebula, astronomers Bradford Smith and Richard Terrile combined three powerful observational techniques to image the disk. They blocked direct light from the star using a coronographic optical system, and employed a CCD detector to allow digital accuracy in their images. To remove scattered light, they imaged a similar star, then digitally subtracted its image from the image of Beta Pictoris, leaving the picture of the nebula.

The resulting image shows the circumstellar disk almost exactly edge-on, and extending some 25 arcseconds from the star, which at its distance of 16 parsecs corresponds to 400 astronomical units. Because the nebula is edge-on, the star's light is dimmed by approximately half a magnitude.

"We have weak evidence for the existence of planets as well as the nebula," says Smith, an astronomer at the University of Arizona. Smith worked with Terrile of JPL to create the picture. Based on the cloud's optical density, the astronomers believe material within 30 AUs of the star has been cleared out, possibly indicating a young planetary system, or planetary system in the process of formation.

Smith and Terrile estimate the mass of the cloud may be up to several hundred Earth masses, depending on its composition. The astronomers expect to use the same technique to search for other circumstellar disks too cool for IRAS to detect. In addition to material around Vega, Fomalhaut, Epsilon Eridani, and Beta Pictoris, IRAS data indicate that protoplanetary disks may exist around other stars as well.

Where Does the Solar System End?

If you put this question to the proverbial "man on the street," you'd probably get "Pluto" for an answer. A more knowledgeable person — aware that Pluto is currently approaching its perihelion — might offer Neptune instead. Or, perhaps, the Oort Cloud — the Sun's far-flung domain of deep-frozen comets. In truth, the edge of the solar system is where the Sun's gravitational field is surpassed by that of the Galaxy as a whole; in short, it's the region over which the Sun can hang onto material indefinitely.

But how far does this extend? Astrophysicists Roman Smoluchowski of the University of Texas and M. Torbett of the Carnegie Institution of Washington have run some computer simulations and come up with an answer. Roughly speaking, the outer limit at which bodies can remain permanently held by the Sun's gravity is 80,000 to 100,000 astronomical units, or 1.3 to 1.6 light-years — about twice as far as the commonly-accepted models for the Oort Cloud. (In comparison, Pluto's average distance from the Sun is 40 AU, or 5.5 light-hours.)

Examined in more detail, the simulations show that when an object's orbit is prograde (that is, with an inclination less than 90°), the outer limit is about 10% to 20% farther out than for retrograde orbits. The authors note that the current population of the outer regions of this volume would be extremely thin because it would not take much of a pertubation from a passing star to move a comet either inward or out. They speculate that the reduced Oort Cloud of today is probably the much-winnowed remnant of the primordial cloud.

Epsilon Aurigae's Secret Companion

Epsilon Aurigae has puzzled astronomers for most of this century. The primary of this eclipsing star system is a yellow-white F supergiant some 4,000 light-years distant. From Earth, it appears as a third-magnitude star located 3° southeast of Capella. Every 27.1 years, *something* eclipses the F star — but no one knows what that something is.

While the period is one of the longest known for eclipsing binaries, the really unusual feature of the eclipse is its duration — nearly two years. This implies that the unknown object is far larger than a normal star. Over the years, astronomers have proposed various exotic models for Epsilon Aurigae's elusive secondary: a swarm of meteorites, a solar system in the making, or even a black hole (see "Mystery Star," ASTRONOMY, August 1983).

The latest eclipse of Epsilon Aurigae began in July 1982, and this time, astronomers were able to monitor the star thoroughly in the infrared, ultraviolet, and visible wavelengths. The new data have led Jack Lissauer of NASA's Ames Research Center and Dana Backman of the University of Hawaii's Institute for Astronomy to a new model for Epsilon Aurigae's secondary. In the November 15, 1984 issue of *Astrophysical Journal Letters*, these astronomers argue that the eclipsing body is actually a pair of stars embedded in a thick disk of gas and dust.

Assuming a typical mass of about 20 suns for the F supergiant, Lissauer and Backman say the eclipse characteristics indicate that it is 2.6 AU in diameter. If placed at the center of our solar system, the star's surface would extend a little past Earth's orbit. The primary and its mysterious companion lie about 30 AU apart (equal to the distance between Neptune and the Sun).

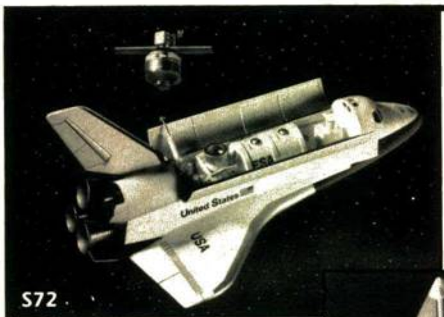
The scientists found that the secondary has a mass of about 16 times that of the Sun. But infrared, optical, and ultraviolet data show the secondary's luminosity is less than 400 times that of our Sun. Lissauer and Backman point out that a 16 solar-mass star has a luminosity at least 100 times greater than that observed from the mysterious companion. They suggest that the secondary is really two stars, each containing eight solar masses of matter. Two such stars are only 10 percent as bright as one 16 solar-mass star.

The infrared data, when combined with the eclipse data, suggest the presence of a disk about 10 AU in diameter and 1 AU thick with a temperature around 500 K. The great extent of the disk explains why the eclipse lasts for two years. The scientists propose that the two hypothetical eight-solar-mass stars are embedded in this disk. Since we view the disk edge-on, most of the stars' radiation escapes through the poles of the disk. This explains why the luminosity we observe from the secondary is less than that of the two stars composing it.

These two stars must be less than 5 AU from one another — otherwise the gravitational force of the primary star would tear them apart. But each star in the secondary should periodically eclipse the other, so Lissauer and Backman suggest astronomers search for variations recurring in as little as a few hours to several months. If their model is correct, such variations should cease in 1997 when the secondary passes behind the primary.

A binary star system embedded in a dusty disk thus joins several competing models that attempt to explain Epsilon Aurigae's mysterious secondary. Will this new model fare better than the others? No one knows yet — with the possible exception of Epsilon Aurigae.

— *Ken Croswell*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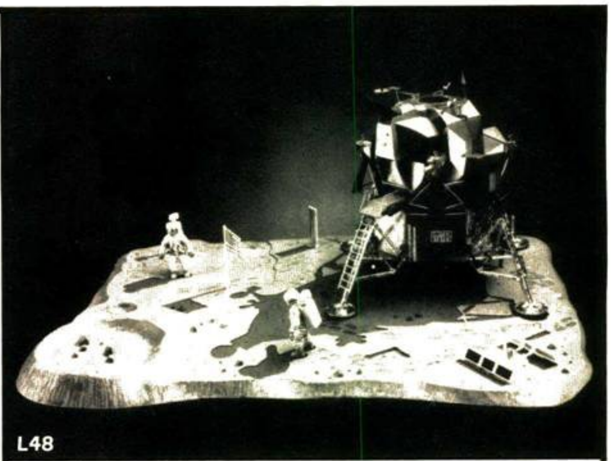
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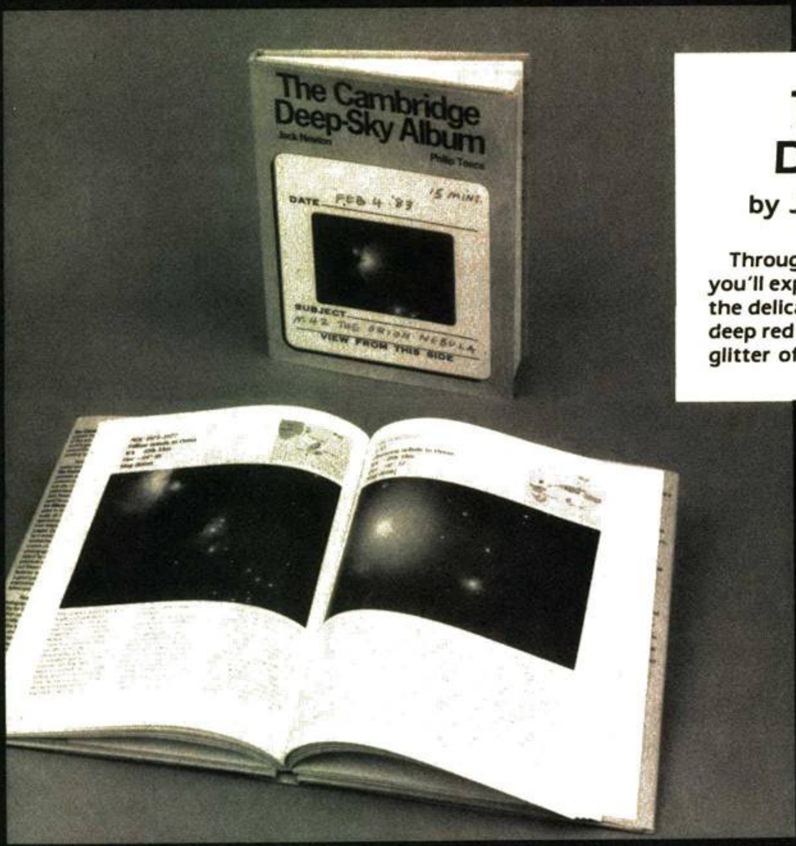
ASTRONEWS

Space Highlights, 1985 to 1990

Name	Event	Date
	1985	
Spacelab-3	Launch of European Space Agency module flown inside Shuttle's payload bay. Spacelab-3 will carry large monkeys for biological experiments. (Because of rescheduling, Spacelab-3 is actually the second full-scale Spacelab mission.)	January 17
Spacelab-2	Launch	April 17
ICE	The International Cometary Explorer passes through the tail of Comet Giacobini-Zinner making the first on-site measurements of a comet and its environment.	September 11
ICE	ICE passes between the Sun and Comet Halley.	October
Giotto	Launch of European Space Agency's probe to Comet Halley.	July
Planet-A	Launch of Japanese craft designed to fly past Halley's Comet.	August 14
Spartan-2	The Shuttle-Pointed Autonomous Research Tool for Astronomy — a re-useable astrophysics observatory. It's returned to Earth after each mission and fitted with new experiments. Spartan-1, launched in August 1984, carried X-ray detectors. Spartan-2 will carry instruments to study the Sun's corona and photograph Halley's Comet.	December 23
	1986	
Voyager 2	Closest approach to Uranus.	January 24
Astro-1	Launch of a re-useable observatory similar to Spartan. Astro's first mission will concentrate its ultraviolet telescopes on Halley's Comet.	March 6
Planet-A	Japanese space probe will fly past Comet Halley at a distance of about 62,000 miles.	March 8
Vega-1	The first of two Soviet probes to Comet Halley will fly past it at a distance of about 6,200 miles.	March 8
Giotto	The European Space Agency's probe to Comet Halley will fly to within 310 miles of the nucleus. Giotto is probably the most advanced of the four spacecraft sent to fly by the comet.	March 13
Vega-2	The Soviet Union's second probe to Halley's Comet flies past it.	March 15
ICE	The International Cometary Explorer passes between the Sun and Comet Halley.	March
ISPM	Launch of the European Space Agency's International Solar Polar Mission, the first probe to study the Sun's polar regions. Launched from the Shuttle, the craft will fly toward Jupiter. Jupiter's gravity will fling the probe back toward the Sun in a path perpendicular to the ecliptic.	May 15
Galileo	Jupiter orbiter and atmospheric probe launched from the Shuttle. Arrives at Jupiter in August 1988.	May 21
Sunlab-1	Spacelab equipment dedicated to studies of *the Sun*.	July 16
Space Telescope	Launch of first large optical telescope dedicated to astronomy to operate above the Earth's atmosphere.	August 13
Astro-2		November 28
	1987	
Spartan-3	Payload designed to perform ultraviolet astronomy launched.	May
ROSAT	The Roentgen Satellite is a German payload launched into orbit around the Earth by the Shuttle. Its mission: to conduct an all-sky survey for X-ray sources for half a year, then to study individual X-ray sources in detail.	September
COBE	The Cosmic Background Explorer will use its sensitive infrared instruments to measure the cosmic background radiation — the faint glow left over from the Big Bang.	December
	1988	
GRO	Launch of NASA's Gamma Ray Observatory to survey the entire sky for high-energy, gamma-ray emitting objects from Earth orbit. Exploding stars, black holes, and the centers of galaxies — including our own Milky Way — emit gamma-rays. GRO will give us our first good look at this high-energy realm.	March
VRM	Launched from the shuttle, the Venus Radar Mapper will arrive at Venus in July. Using radio beams to penetrate the planet's thick atmosphere, the craft will make a detailed map of the venusian surface, revealing features as small as 120 meters across.	April
EUVE	Another Earth-orbiting survey satellite, NASA's Extreme Ultraviolet Explorer will examine the only neglected portion of the electromagnetic spectrum. Extreme ultraviolet light has slightly less energy than X-rays, but slightly more than ultraviolet light. EUVE will survey the entire sky for sources, then provide a detailed look at the most interesting objects.	December
	1989	
Voyager 2	Closest approach to Neptune. With this, Voyager's long planet-hopping mission will end, though the craft will continue out to the solar system's heliopause.	August 24
SOT	Although technical problems have caused many delays, the Solar Optical Telescope is now scheduled for a Shuttle launch sometime this year. SOT would examine the Sun in visible light and in the ultraviolet. SOT would be able to see features on the surface of the Sun as small as 40 miles.	?
	1990	
MGCO	A Mars Geoscience/Climatology Observer will be built from one of the many weather or communications satellites now in use. Outfitted with new instrumentation and launched from the Shuttle, such a probe could enter into orbit around the planet in 1991. Geologists would like another look at the surface of Mars, and meteorologists would like a further analysis of the planet's weather patterns. MGCO has been funded, with launch planned for sometime this year.	?



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ASTRO NEWS

Photographing the Rings of Uranus

For the first time, astronomers have clearly photographed the rings of Uranus, showing them to be made of particles darker than any other bodies in the solar system. Richard Terrile of NASA's Jet Propulsion Laboratory and Bradford Smith of the University of Arizona used a charge-coupled device (CCD) to record the system.

The rings are darker than charcoal and lie very close to the much brighter Uranus, making it difficult to photograph them. Special computer processing was necessary to make the rings visible. (The three-dimensional appearance of the image is an artifact of the processing.)

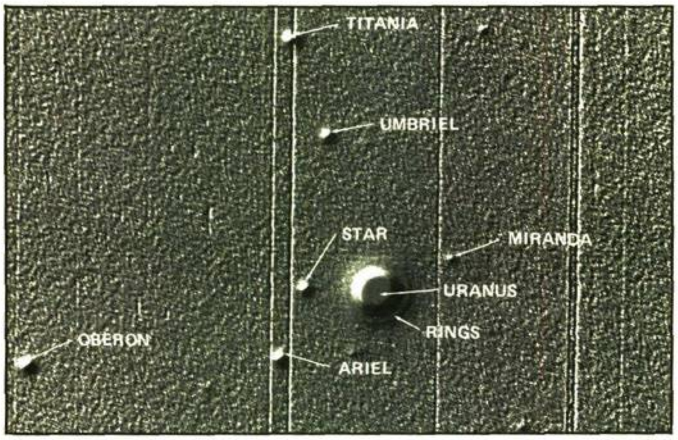
Uranus' rotation axis has a 98° tilt with reference to its orbit. At present, we are viewing the southern pole of Uranus nearly face-on, so the rings make a concentric circle around the disk of the planet. The image also shows the five known moons of Uranus along with a background star. The prominent vertical lines are caused by minor defects in the detector chip.

The rings — nine in all — were discovered in 1977 when they blocked the light of a distant star as Uranus passed in front of it. All the rings are very narrow; the widest of them, called the Epsilon ring, has an average width of about 50 kilometers. (The image shows the ring system as a whole and does not resolve the individual narrow rings.)

Analysis of this photograph shows that the rings reflect only about two percent of the sunlight falling on them, making them the darkest material in the solar system. What are the rings made of? Two possibilities have been suggested. Evidence from meteorites and astronomical observations of asteroids hint that dark organic material is prevalent in the outer solar system and might make up the rings.

Another possibility is that the rings are frozen methane, which is another common material in the outer solar system. Methane ice, normally bright and reflective, can be darkened by radiation, either high-energy particles from the Sun or radiation trapped around Uranus (similar to the van Allen radiation belts around Earth).

Studies of the rings of Uranus are particularly important because they will contribute to preparations for Voyager 2's encounter with the planet a year from now — mankind's first opportunity to view the rings close-up.



JPL/NASA

ASTRO CALENDAR

January 13-16
Meeting of the American Astronomical Society (professional meeting), Tucson, Arizona. Contact: AAS, 1816 Jefferson Pl. N.W., Washington, DC 20036.

February 15-17
First Annual Winter Star Party, Everglades National Park, Florida. Sponsored by the Southern Cross Astronomical Society. Contact: Richard Fagin, P.O. Box 152, Miami, FL 33197. Phone (305) 233-5165.

April 11
Third Annual Space Awareness Day, Commerce, Texas. Hosted by the East Texas State University Science Fact-Science Fiction Society. Contact: Dr. John Lamb, Jr., 2812 McCarley, Commerce, TX 75428.

April 18-21
National Convention of the National Science Teachers Association, Cincinnati, Ohio. Contact: NSTA, 1742 Connecticut Ave. N.W., Washington, DC 20009.

April 27
Astronomy Day. For more information, contact: Gary Tomlinson, Astronomy Day Coordinator, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503. Phone (616) 456-3985.

April 27-28
Abell Memorial Weekend (in memory of George Abell). Teacher's workshop and public lecture series on new developments in astronomy. Jointly sponsored by the Astronomical Society of the Pacific and the University of California-Los Angeles. Contact: Andrew Fraknoi, Abell Workshop, A.S.P., 1290 24th Ave., San Francisco, CA 94122. Phone (415) 661-8660.

May 15-19
Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: TSP '85, Dept. A, 128 N. Commerce, Burleson, TX 76028.

May 22-24
IAPPP Big Bear Symposium, Camp Oaks, Big Bear Lake, California (same location as Riverside Telescope Maker's Conference). Contact: Rev. Donald L. Rohe, 957 W. Marshall Blvd., San Bernardino, CA 92405. Phone (714) 383-4731 or (714) 883-7923.

May 24-27
Riverside Telescope Maker's Conference, Camp Oaks, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Ave., Riverside, CA 92505. Phone (714) 689-6893.

June 9-12
Southeastern Planetarium Association Annual Conference (professional conference), Land Between the Lakes, Kentucky. Contact: Doug Gegen, Conference Coordinator, Visitor Center, Land Between the Lakes-TVA, Golden Pond, KY 42231. Phone (502) 924-5602.

June 28-July 1
Royal Astronomical Society of Canada General Assembly, Edmonton, Alberta, Canada. Contact: RASC, Edmonton Centre, c/o Edmonton Space Sciences Centre, 11211-142 St., Edmonton, Alberta, Canada T5M 4A1.

July 15-24
International Space Week '85, Cocoa, Florida. Contact: Florida Spaceweek Committee, 993 Macco Rd., Cocoa, FL 32927.

Meeting notices to appear in AstroCalendar must be submitted at least four months in advance of the meeting date. Most organizations appreciate your enclosing a long (business-size) self-addressed, stamped envelope along with your request for information.

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ANNOUNCEMENT — The Society of Amateur Radio Astronomers (S.A.R.A.) invites you to participate. Monthly journal, annual symposium, books, computer programs, international membership. $20/year. Contact S.A.R.A., P.O. Box 6020, Wheeling, WV 26003-0701.

ANNOUNCEMENT — The Yuma Astronomy Club meets once a month at 7:30 p.m. each Wednesday before the New Moon at the Yuma City-County Library. A star party is held the following weekend. For more information, contact Gilbert Lugo, 875 W. 21st St., Yuma, AZ 85364. Phone (602) 726-7423.

ANNOUNCEMENT — The Smoky Mountain Astronomical Society meets the second Friday of every month at the Student's Museum on Magnolia Avenue in Knoxville, Tennessee. A newsletter is also published monthly. Cookies and cokes are served at the meetings. For more information, phone Ken at (615) 637-1121.

ANNOUNCEMENT — The William Herschel Society will present its annual lecture on Friday, March 8 at 7:30 p.m. in The Pump Room, Bath, England. Dr. Hughes will speak on Halley's Comet. The lecture is sponsored by British Aerospace. For tickets/details, contact the William Herschel Society, 19 New King St., Bath, England. Phone Bath 336228.

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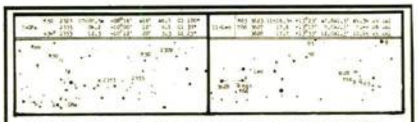

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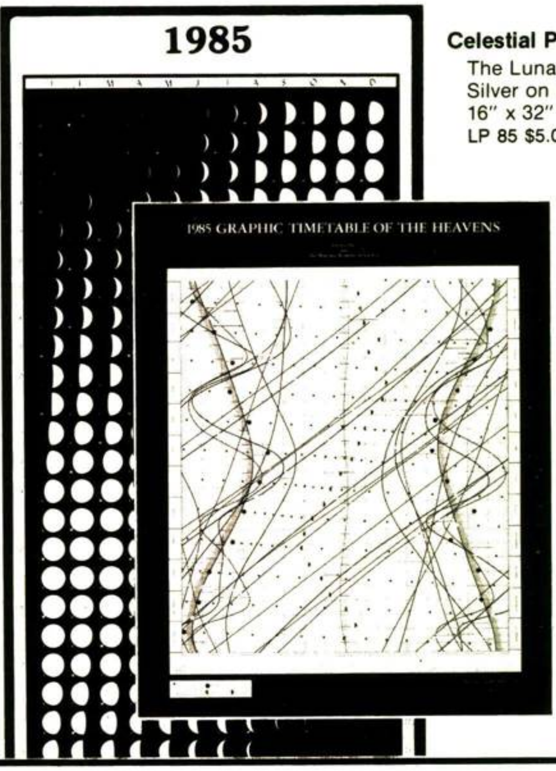

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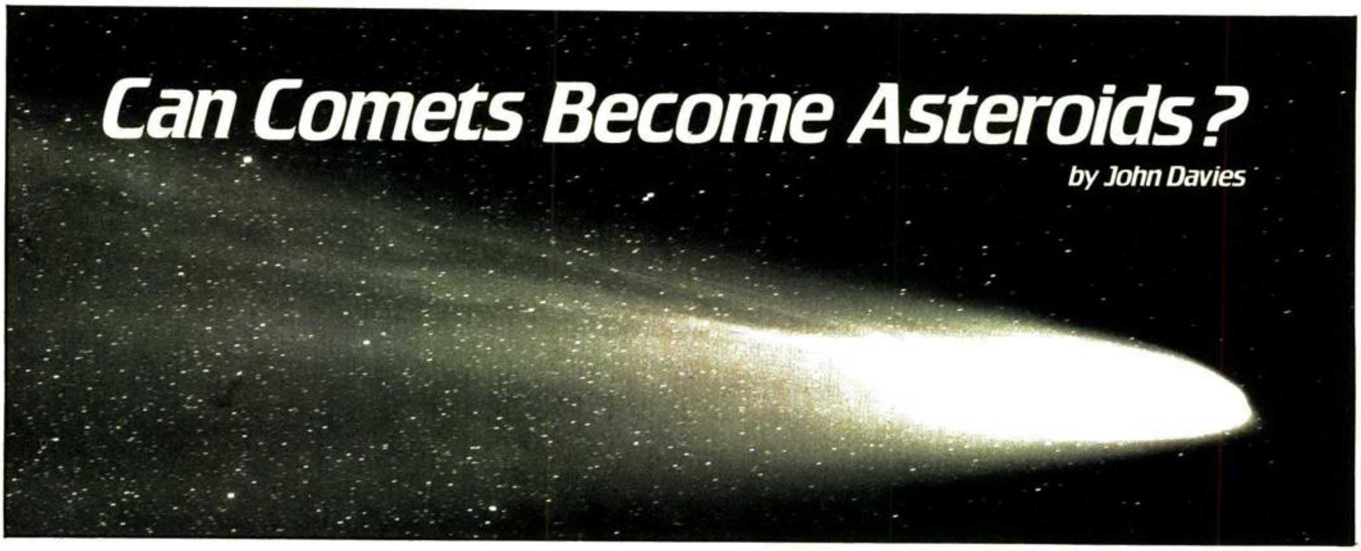


Can Comets Become Asteroids?

by John Davies

Palomar Observatory

As long as astronomers have studied them, asteroids and comets have been classed as distinctly different inhabitants of the solar system. Comets are dirty icebergs, most of which travel around the Sun in orbits carrying them a thousand times farther out than Pluto. Only when they swing inward, close to the Sun, do their ices become active and outgas large amounts of matter. Asteroids are rocky bodies with near-circular orbits that hold to the inner solar system. A few are large — several hundred kilometers across — but most are far smaller. Once thought to be the debris of an exploded planet, asteroids are planetesimals — small bodies which never coalesced into one body because of nearby Jupiter's gravitational tug.

The differences between asteroids and comets are best shown by considering where each originated. The solar nebula — that cloud of gas and dust from which the Sun was born — originally contained huge amounts of icy material. Heat from this infant star, however, drove most of the lighter gases from the inner solar system and left behind heavy elements which formed the terrestrial planets. In the outer solar system, where the Sun's radiation was considerably less intense, hydrogen gas dominated and, by combining with other materials, gave rise to methane, ammonia, and water ice. Still farther out, where these elements existed in abundance, about two trillion comets formed a huge shell around the Sun called the Oort Cloud (see "Backtracking the Comets," ASTRONOMY, August 1982). The question now arises: Did asteroids form where they're found — between the orbits of Mars and Jupiter — or are they burned-out comets which formed near the edge of the solar system, but were captured and gravitationally bound to the inner solar system?

A comet would need to undergo two dramatic changes to evolve into an asteroid — or, more strictly speaking, into something that can't be distinguished from an asteroid using ground-based observations. First, the comet must move away from the Oort Cloud to a stable orbit in the inner solar system. Second, it must reduce activity until it becomes merely a burned-out, inactive piece of rock. To drastically change a long-period comet's orbit is no easy trick, since it is basically a floating ball controlled entirely by gravity. Even when comets encounter one of the larger planets — such as Jupiter — and become "trapped" into a short-period orbit, their path is rarely stable. Usually such a comet will soon re-encounter Jupiter and get flung back out into deep space, possibly escaping the Oort Cloud completely.

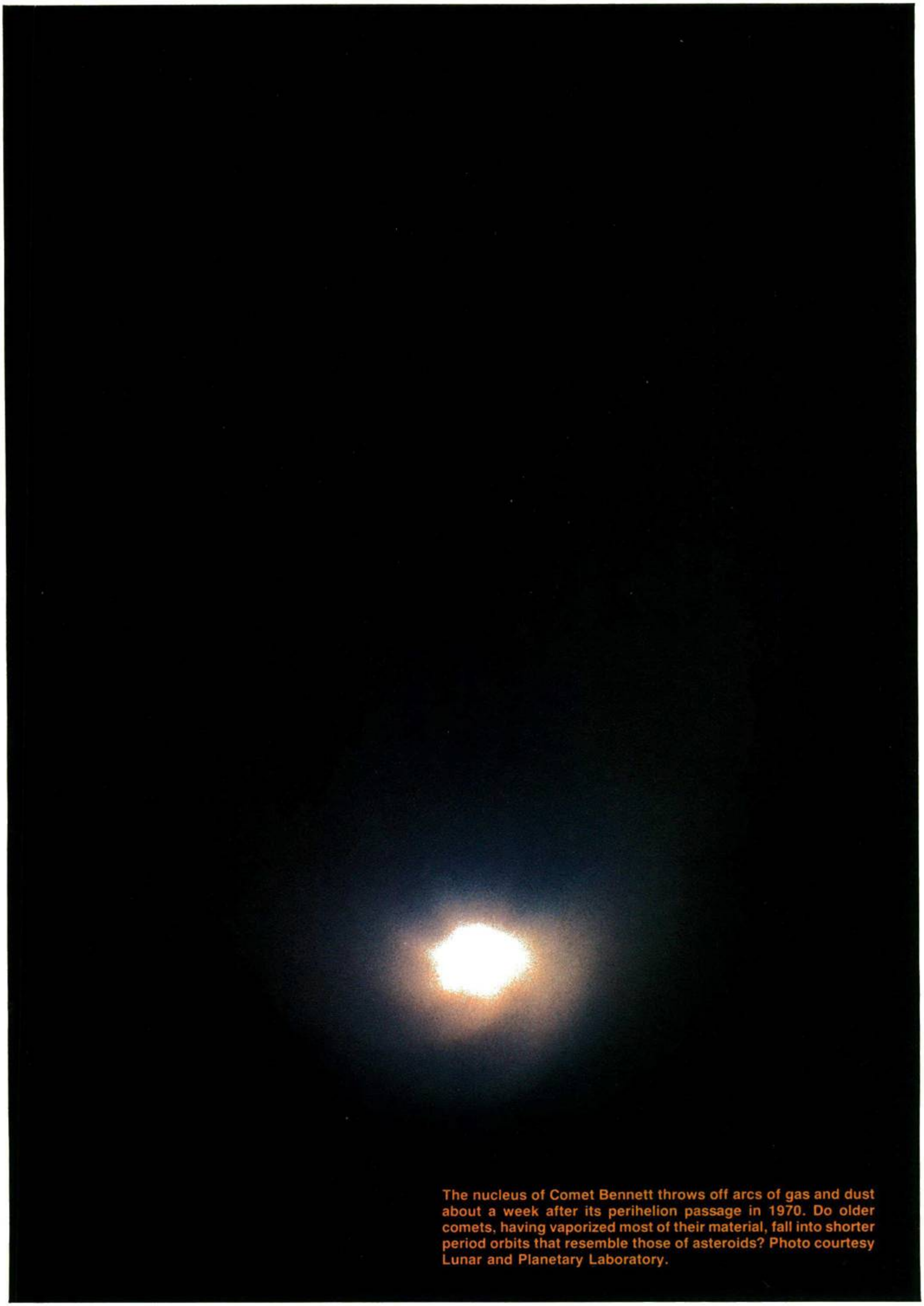
A short-period comet, however, might be able to evolve a stable orbit, but only if it could carry its own propulsion system. A comet becomes active when gas and dust vaporize from its nucleus; this stream of vapor acts like a rocket exhaust and produces an equal and opposite force on the nucleus. If this gas and dust were dispersed perfectly uniformly in all directions, the forces would cancel out and have no effect on the comet's trajectory. But this seldom happens and a comet's deviation from its expected orbit can be significant. These non-gravitational forces can cause a comet's orbit to change so that it no longer risks close approaches to Jupiter, but instead follows a stable path within the inner solar system. Encke's Comet, with a 3.3 year period, is such an object.

Once in a stable, if somewhat eccentric, short-period orbit, a comet like Encke will make repeated passages close to the Sun. Each time it passes through perihelion, Encke loses some of its outer layers — about one meter's worth per orbit. The solar wind removes the gas and small dust particles permanently, but heavier silicate particles are pulled back onto the nucleus by the comet's feeble gravitation. Gradually, an insulating crust builds up; this protects the icy inner regions of the nucleus from heat and to a large extent, the comet "turns off." But such an insulating crust may not be very strong; impacts by interplanetary debris may puncture it and expose the ice, causing the comet to outburst and brighten unexpectedly. As long as the crust is undisturbed, however, the comet may look just like an asteroid to the eyes of astronomical observers. Are any old comets masquerading as asteroids?

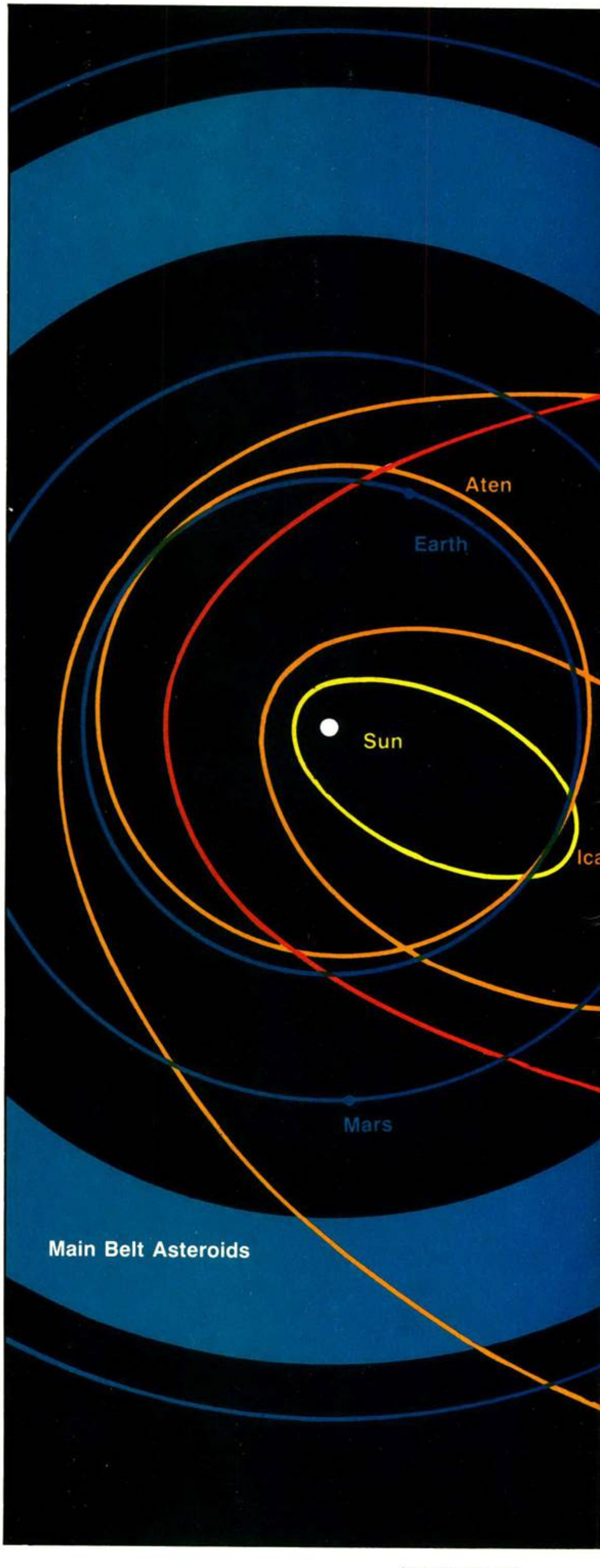
A variety of unusual objects which may represent a link between comets and asteroids have already been found. In 1977, Caltech astronomer Charles Kowal discovered asteroid number 2060, which he named Chiron. Kowal found that Chiron maintains an unstable orbit between Saturn and Uranus. In a few million years, the gravitational influences of the giant planets will conspire to change Chiron's orbit radically, either ejecting it from the solar system or moving it toward Jupiter. If the latter happens, Chiron might be injected into a short-period orbit which swings it close to the Sun.

If Chiron *is* the nucleus of a comet, it is 10 times larger than any known at present. The current record-holder is the periodic comet Schwassman-Wachmann 1, which measures about 40 kilometers across and follows a 15-year, near-circular orbit just beyond Jupiter. This object normally appears star-like, but occasional outbursts reveal it to be a comet. So far, Chiron has shown no outbursts — hardly surprising considering its great distance from the Sun. Adding to the puzzle, however, is the fact that visible and infrared photometry suggest that Chiron resembles a carbonaceous asteroid, not an icy comet! If it is a comet, it must be heavily covered with a layer of carbon-containing dust. But if it's an asteroid, what's it doing out there?

Somewhat closer to the Sun is asteroid number 944, the unusual object named Hidalgo. Discovered in October 1920 by the astronomer Walter Baade, Hidalgo is estimated to be 30 kilometers in diameter; its highly eccentric 14-year orbit ranges between two and 10 astronomical units from the Sun. Despite a comet-like orbit, Hidalgo shows no other signs of activity. It is classed as a member of the RD (reddish and dark) asteroids. (Interestingly, Comet Schwassman-Wachmann also appears reddish and dark when inactive, which may imply an evolutionary relationship.) Hidalgo displays significant changes



The nucleus of Comet Bennett throws off arcs of gas and dust about a week after its perihelion passage in 1970. Do older comets, having vaporized most of their material, fall into shorter period orbits that resemble those of asteroids? Photo courtesy Lunar and Planetary Laboratory.



A slice of the inner solar system shows relative positions of planets, asteroids, and a typical parabolic comet. Most asteroids reside in the "main belt" between Mars and Jupiter, though some (such as Apollo, Aten, and Icarus) have orbits crossing the inner planets. Hidalgo has the largest orbital path of any asteroid — one so atypical astronomers believe it was once a comet.

in color as it rotates — possibly the result of weak activity in a small area on an otherwise defunct cometary nucleus.

Hidalgo is not the only asteroid in a comet-like orbit. Two other objects discovered in 1983 were also given temporary designations as asteroids. In September 1983, the Swiss astronomer Paul Wild discovered 1983 SA. He classed it as asteroidal from photographs taken shortly after its discovery, although its orbit lies inside Mars at perihelion and well beyond Jupiter at aphelion — resembling that of a short-period comet. Its orbital inclination with respect to the plane of the solar system is 30° — also much like a comet's. Slightly less eccentric is the Mars-grazing object 1983 XE, discovered in December 1983 by American astronomers Ted Bowell and Brian Skiff at Lowell Observatory. This object was described as having a "cometary" orbit, but astronomers found no trace of a coma or tail in long-exposure photographs. The same holds true for the periodic comets Neujmin I and Arend-Rigeux. Although classified as comets when they were discovered, both appeared stellar in subsequent orbits and are now referred to as dead comets.

The strongest link between asteroids and comets, though, lies in the inner solar system. The Apollo-Amor asteroids are objects which cross Earth's orbit and exist in relatively large numbers. On the other hand, infrequent but inevitable collisions with Earth or the other inner planets is steadily thinning their numbers — which calls for an ongoing source of new Apollo-type asteroids, either from the asteroid belt, or inactive comets. The latter possibility received a boost when asteroid 1983 TB was discovered by the IRAS satellite. 1983 TB's orbit is almost indentical to that of the Geminid meteor stream — long believed to be the remnant of a now-extinct comet (see "IRAS and the Infrared Universe," ASTRONOMY, March 1984). When first discovered, 1983 TB behaved just like an asteroid and showed no activity, but its orbital similarity to the Geminids strongly suggested it was once a comet. Other candidates which might be extinct comets masquerading as Apollo asteroids are 2201 Oljato and 2101 Adonis — both of which may be related to meteor streams — and 2212 Hephaistos whose orbit resembles that of Encke's Comet.

Despite these examples, many astronomers remain unconvinced of a link between comets and asteroids and argue that much of the evidence is circumstantial. Chiron, they say, is too large to be a normal comet and there is no observational evidence supporting an icy nature. Hidalgo, too, is larger than most comets, although not radically so, but its lack of activity near the Sun tends to confirm a rocky nature. The large color variations during rotation would then be due to differing surface composition, not outgassing. Skeptics also point to calculations which show Hidalgo passed close to Jupiter in 1673. This supports the idea that it is an escaped Trojan asteroid, as suggested by its color. Chiron, too, has a checkered orbital past and may well be just a strayed asteroid.

Although the asteroidal appearance of some comets and the

Asteroids and Comets: An Orbital Link?

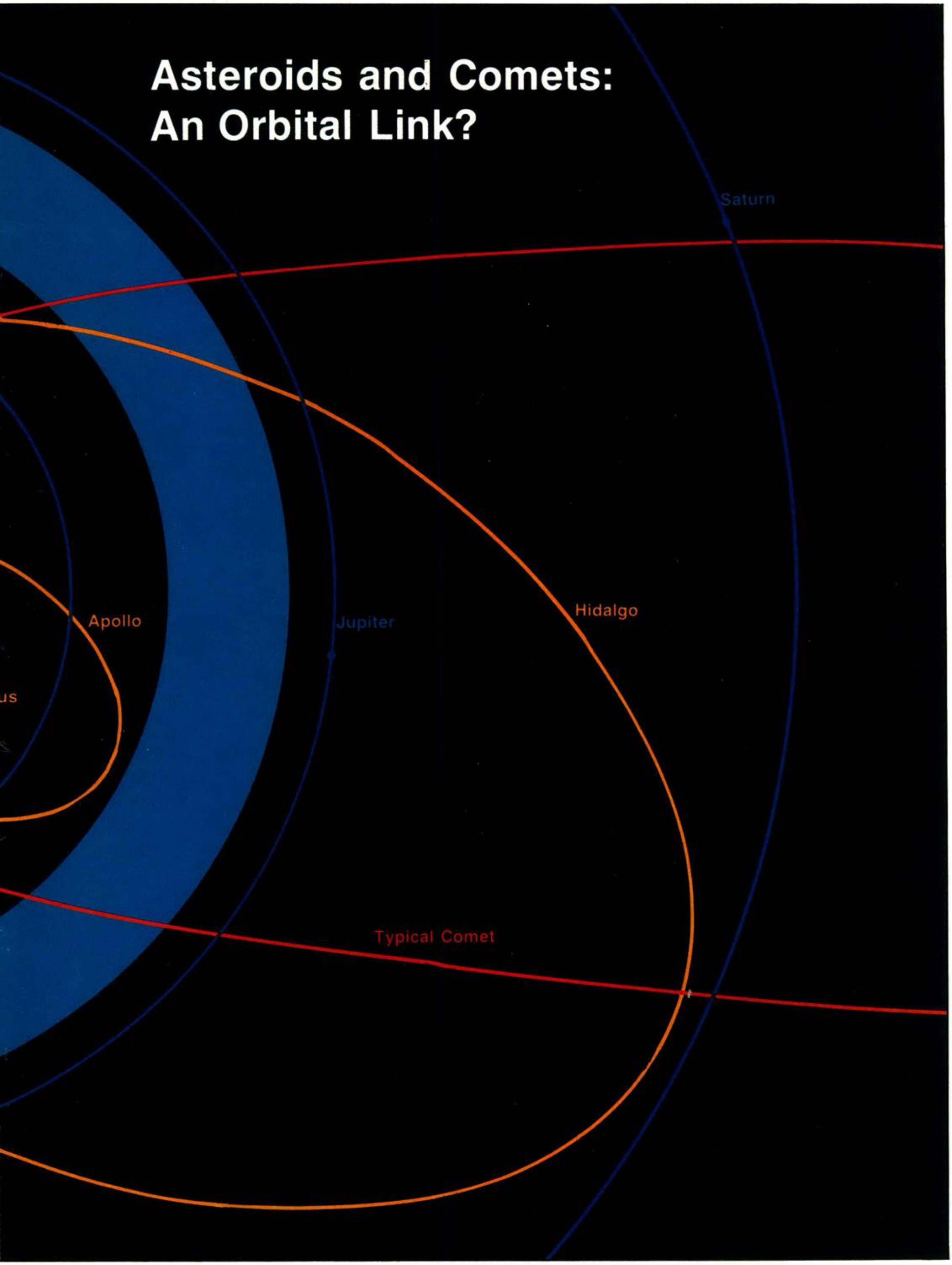
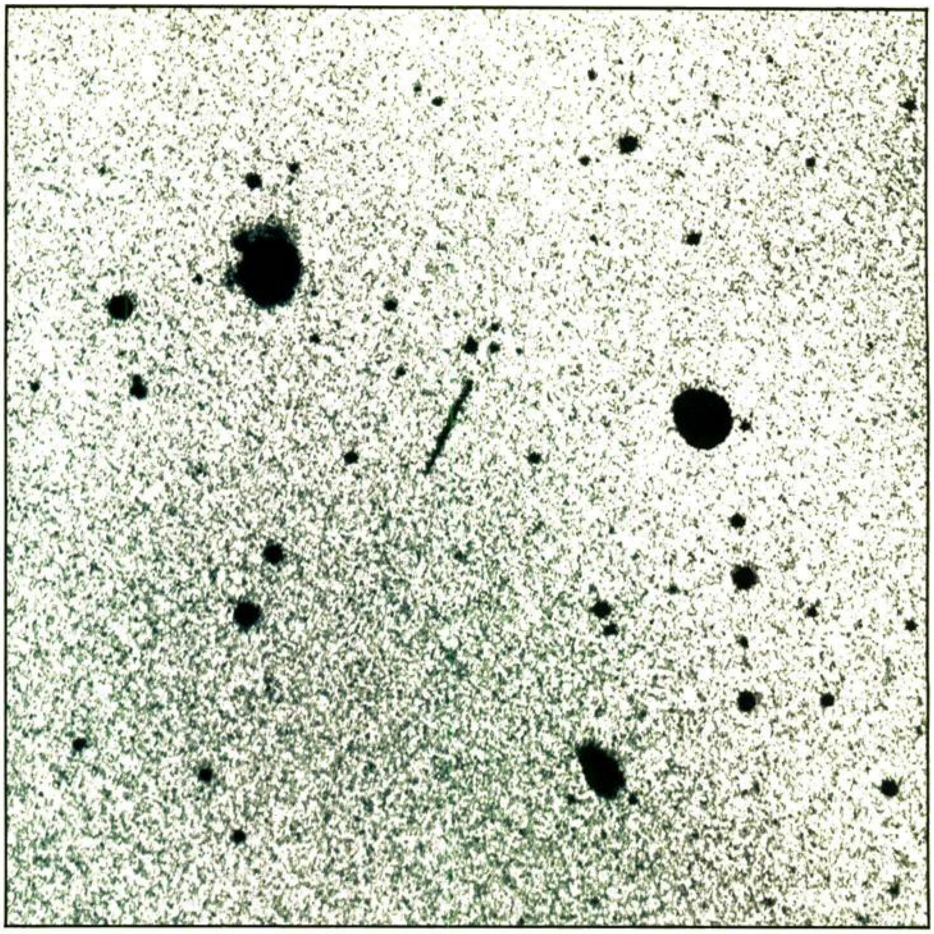

Saturn
Hidalgo
Apollo
Jupiter
us
Typical Comet

Diagram by Thomas L. Hunt



A typical Apollo asteroid, 1976 UA was discovered by Eleanor Helin in 1976 at Palomar Observatory. At a glance, asteroids and comets look similar on discovery plates like the one shown here — only after analyzing motion, brightness, and other characteristics can they be identified. Photo courtesy Palomar Observatory.

discovery of asteroids in cometary orbits suggests an evolutionary link, distant comets often appear stellar and may only become active for a short period, possibly even when unobservable. Recent observations of Neujmin I show evidence of a weak coma, and the newly discovered objects 1983 SA and 1983 SF have not been observed thoroughly enough to rule out a cometary nature. The difficulty of distinguishing faint comets from asteroids is shown by the case of 1983 JG — originally classified as a minor planet but later found to be a prediscovery image of Comet Kowal-Vavrova.

Asteroid Oljato: A Defunct Comet?

A paper published in the October 5, 1984 issue of *Science* proposes that the asteroid 2201 Oljato, a small Venus-crosser that revolves around the Sun in a period of 1770 days, is actually a dead comet. Authors C.T. Russell and M. Arghavani of UCLA, and R. Aroian and K. Nock of NASA's Jet Propulsion Laboratory, detected periodic magnetic field enhancements with the Pioneer Venus spacecraft. Originally thinking an outgassing comet may have passed nearby the spacecraft — an event which would cause the detected change in the magnetic field — the astronomers determined that asteroid Oljato seemed to be associated with about one-fourth of the enhancements.

After closely studying the geometry involved, however, it became evident that Oljato itself could not have caused the changes in the magnetic field. These enhancements, the astronomers concluded, were due to interactions between the solar wind and debris trailing behind Oljato. These findings indicate Oljato is a dying comet, locked in a short-period orbit in the inner solar system, but still feebly outgassing cometary material.

What about the 1983 TB/Geminid connection? Although it provides strong support for the link between Apollo asteroids and comets, astronomers still haven't reached any definite conclusions. At aphelion, 1983 TB lies deep inside the asteroid belt where a collision with another asteroid could chip off enough material to produce the Geminids. The connection between meteor streams and other Apollo asteroids is less convincing and may only be coincidental.

Fred Whipple, the Harvard Observatory astronomer who in 1950 created the currently popular icy snowball model for comets, remains unconvinced. He points out that meteorites, objects of rock or nickel-iron which have been subjected to heating and high pressures, are linked to the orbits of Apollo asteroids. It would be impossible, he says, to produce such high temperatures inside a comet's nucleus, therefore Apollo objects cannot be inert comets. Whipple also points to several comets which have faded away without leaving asteroid-like cores. For example, periodic Comet Brorsen made five appearances between 1846 and 1879, then vanished altogether. Biela's Comet, which split in two between appearances in 1832 and 1845, produced a spectacular meteor shower but left no burned-out rock behind.

Will astronomers solve this intriguing puzzle? Possibly, but first they'll need more detailed studies of suspected "transition objects" in order to search for any trace of a coma and to identify surface compositions. Second, they must observe known comets at large distances from the Sun when their activity is low and their bare nuclei may be visible. Finally, they must continue searching for possible asteroidal cores of extinct comets. Until these observations are made and the verdict is in, the question of a link between comets and asteroids remains tantalisingly unanswerable.

John Davies is Professor of Astronomy at the University of Leicester in England. He is also a member of the IRAS Science Team.

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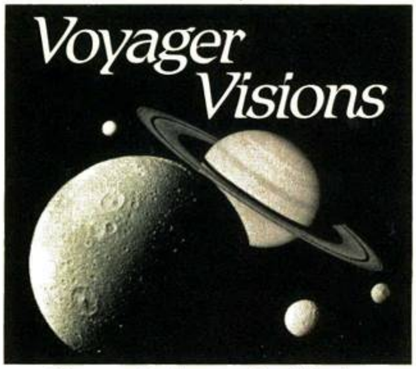

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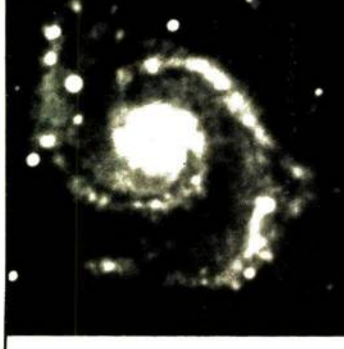

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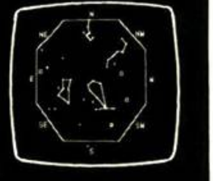

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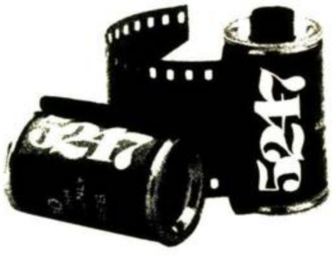

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Twinkle Little Star: How to Enjoy Variables

by David H. Levy

Stars are people, too.

Of course! People get born, and so do stars. Just as children grow up, stars mature too. They both grow old. And just as death and taxes are certain for us, so too are death and . . . Well, there *are* some differences.

Stars and people share another quality: they have moods. A young star might flicker with the unpredictability of a temper tantrum, unable to decide, it seems, on its future course. As it gets older, it might acquire the dignity of middle age by staying out of trouble and perhaps bearing the responsibility of lighting and heating life forms.

Old age does strange things to a star. A red giant, for example, may begin varying again, but this time to the slow and measured beat of an aging stellar heart. Or the star may become unpredictable, varying over time with graceful but irregular pulses. Another star might become erratic as it struggles for its final gasps of hydrogen. Bursting its seams in a cry for "help," it may stun an entire galaxy as it bows out of life. But even afterwards, its tiny heart will live on in the clockwork tick of a pulsar.

These are the variable stars. In strange ways they mirror us. A philosopher might add this is more than coincidence. Consider, for example, the ancestral star whose dying legacy may have been the carbon that started *us*. In a very real sense, we are part of the stars and when we watch them, we watch ourselves.

Variable star observing is easy, the technique basic, and the principle simple. Before beginning, however, we must remember that success in this endeavor (like that for any other type of observing) involves three factors which must work together.

The telescope. You need an instrument that fits your needs, a size you can work with, and a type that lends itself to variable star observing. I worry about using refractors for this work because unless their color correction is absolutely perfect, red stars and blue ones will not display their correct relative magnitudes and your estimates will be off. And although popular, Schmidt-Cassegrains, with their inverted fields, do not easily accommodate the orientation of the standard AAVSO (American Association of Variable Star Observers) star charts. My preference is the good old-fashioned Newtonian reflector. In fact, even the faintest stars in this article are observable with a 6-inch Newtonian.

The observer. When *you're* down, don't look up. Avoid variables if you've had a bad day. Although fun, they require patience and accuracy to observe properly. Personal moods, I have noticed, can affect the quality of estimates. Most important, comfort is a must! Tired or strained eyes can play tricks and render your observations useless.

The sky. A clear sky, especially one without haze or cirrus clouds, is essential.

When all three factors are working in harmony, your setup is wired for good and honest results.

Star 1: Delta Cephei

Let's begin with simplicity itself: the star Delta Cephei. This Cepheid, with a period of light variation a little under a week, offers you slightly different brightnesses to view each night. Begin by looking at your star chart. Delta Cep has two neighbors — Zeta and Epsilon. Assign Zeta an arbitrary value of "1" and Epsilon a value of "5." Tonight, if the sky is clear, observe the Delta Cep triangle with binoculars — or even the naked eye. Record your estimate as follows:

1 — if Delta Cephei is as bright as Zeta;
2 — if it is slightly fainter than Zeta;
3 — if it is midway between Zeta and Epsilon;
4 — if it is slightly brighter than Epsilon;
5 — if it is about the same brightness as Epsilon.

Try this every night and don't give up until you are estimating with a fair degree of confidence. Later, you can use 1.5 or 2.5, etc., for intermediate stages of brightness. You will thus be estimating to about a tenth of a magnitude.

Star 2: R Scuti

When summer arrives, try something new. You've mastered the first simple step with Delta Cep! Now we're leaving the Triple-A Minors for the fun and excitement of the Major Leagues. Look carefully at the chart for R Scuti, an irregular variable. First, find the circle-and-dot that represents the variable at maximum and minimum brightness. Little numbers — like 61, 67, and 71 — are printed near some of the other stars. These are magnitudes that have been accurately determined. The decimal is omitted to avoid confusion with star dots.

Is R Scuti brighter than the 6.7 star, but fainter than the 6.1? Or does its brightness fall somewhere between the 6.7 star and the 7.1? Let's say that it's between the 6.1 and the 6.7 star. Now do the same thing you did with Delta Cep, except use the real magnitudes:

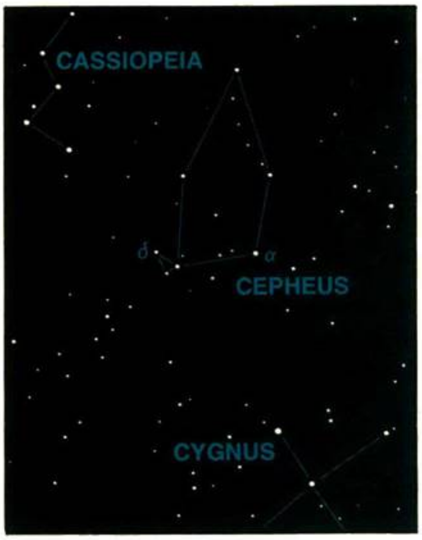
6.1 — if R Scuti is as bright as the 6.1 star;
6.2 — if it is slightly fainter than the 6.1;
6.3 — if it is considerably fainter than 6.1;
6.4 — if R Scuti is midway between the two stars;
6.5 — if it is considerably brighter than the 6.7;
6.6 — if it is slightly brighter than the 6.7;
6.7 — if R Scuti is as bright as the 6.7 star.

Congratulations! You have now made a variable star estimate in the tradition of some four million observations sent to the AAVSO since 1911.

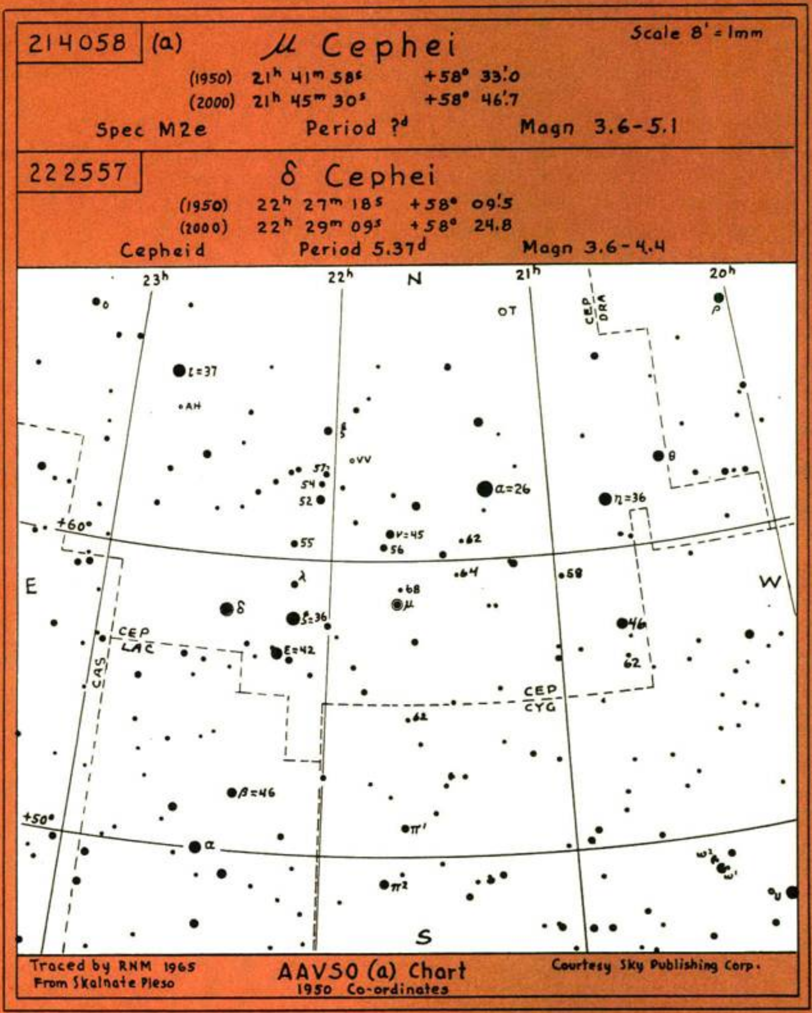
Wasn't it fun? I ask this question with some trepidation, because after I tried estimating a variable for the first time I resolved never to point my telescope within 10 degrees of *any* variable in the whole sky — *ever again*.

But what if R Scuti doesn't cooperate? What if you look at it, and it seems to *mysteriously brighten?*

This could be due to the *Purkinje effect*. Red light builds up on your retina — in somewhat the way it does on photograph-



Cepheus, located between Cygnus and Cassiopeia, resembles a child's drawing of a house. The triangle containing Delta and its two comparison stars is easy to spot once you know where to look.



Delta Cephei (naked-eye chart)

Charts reproduced by special permission from AAVSO director Janet A. Mattei.

ic film — and this build-up makes the star appear to brighten. Although R Scuti is a very red star, there are ways around this annoying "red light" effect on your eyes using the variable observer's tricks of the trade. First, try glancing quickly and repeatedly at the star instead of staring at it. Second, don't look at the star directly; look to one side. This is called averted vision. Third, set your binoculars or telescope slightly out of focus. The subtle balls of light that result are sometimes easier to compare for brightness than sharp stellar pinpoints.

You might as well get used to this problem, though. It's especially prevalent in red stars, and lots of variables are red!

Star 3: Omicron Ceti

Fourteen years *before* Galileo turned his telescope skyward, David Fabricius noticed a fairly bright star in Cetus. No big deal — Cetus has lots of fairly bright stars. But over the following weeks, he noticed something that was not quite normal — the star gradually disappeared! Fabricius saw the star again in 1609 — the year Galileo began using his telescope. By 1639, a number of sightings confirmed that this star didn't really disappear, but actually increased and decreased in brightness.

The task of sighting that star — called Omicron Ceti or Mira — is much easier nowadays, since charts of its position exist. But the excitement of discovery and observation remains unchanged, even though Mira has cycled through 370 periods in the interval. You need two charts: one made for the star during the bright half of its period when it is visible in binoculars, and one showing star magnitudes that are helpful for telescope use.

How often should you estimate Mira's brightness? Every night? Ha! With an 11-month period of variation, you've got to be kidding! Try looking every two weeks. This way, you'll get a smooth light curve and new observations won't be prejudiced memories of the old.

Because of their similar nature and behavior, thousands of stars are known as *Mira variables*. What they share is a large brightness change (between four and eight magnitudes) over several months' time. However, neither the range of brightness nor the period of any Mira star is precisely predictable. Mira herself still pulls enough tricks and surprises to be well worth watching. Why not watch Mira this spring?

Variable Stars

How many kinds of variables are there? We've looked at Cepheids, Irregulars, and Miras. That makes at least three.

Actually, there are over 20,000 types of variable stars! That's right, 20,000! Whenever we try to classify variables, we always run into exceptions; when we create new categories to include the "exceptions," these turn out to have exceptions as well. In a very real sense, every variable star in the sky — each of the some 20,000 that have been discovered — is in a class by itself.

Some classifications are broad enough to be obvious. You'd never confuse a stately and mature red giant like Mira with a little dwarf nova that slobbers over itself every two months. A nebular variable, which changes magnitude for neither rhyme nor reason, would not be confused with a slightly senile semi-regular. Similarly, the eclipsers revolving together in music-box rhythm are not the same as the intrinsic clockwork ticking of the Cepheids. But beyond these basic differences, classifying the variables is difficult. Let's take a look.

Pulsating Stars

Cepheid variables are stars whose mean brightnesses are proportional to their periods. This means that if we measure the period of a Cepheid, we know how luminous it is. This has helped determine distances to nearby star clusters and galaxies. A shining example is Delta Cephei with a period of about 5.366341 days — give or take a few millionths of a day. While stars of Delta Cephei's ilk belong to the flat component of our Galaxy, another type (led by W Virginis) inhabits the spherical part. Their periods are somewhat longer, with W Vir's at about 17 days.

But that's not all. Cepheids can also have extremely short periods. RR Lyrae varies in only ⅗ of a day, and other stars of this type have periods of less than an hour. Even this subdivision has sub-subclasses, which are usually determined by the shape of their light curves.

You could spend your whole life looking at the Cepheids. But watch out — there are so many, you'd never have time to eat, sleep, or anything else!

Long Period Stars

This class has so many different examples of variation that I call them "kitchen sink" stars. They are lumped together into one group only because detailed classification would be a nightmare. Every one's unique: R Leonis occasionally stalls on the approach to maximum; X Cam varies through three cycles each year; Chi Cygni has been known to drop 11 magnitudes. Some Mira stars reach maximum quickly; others rush to minimum. To call the whole class after Mira — "the wonderful" — reveals a basic truth about these stars.

And lest we forget, strange stars like R Ursae Majoris are also relatives of the Miras, although their curves are shallower than those of the classical Miras and not quite as regular. These "semi-regulars" aren't all the same, either. VZ Cam, for instance, has a period of 24 days (though I have never seen it vary much at any time) and Betelgeuse pulsates very slow-w-ly over 5.7 *years*.

Eruptive Stars

Cute. So convenient to class all variables that erupt or explode into one group. Just like atomic bombs and popcorn, right? Exploders.

Let's take a look at these strange bedfellows.

First we have *Orion stars*, whose tiny flickers are associated with the nebulosity that surrounds them. Anyone who has looked carefully at these stars knows each is different and their light curves have little in common with one another. Some Orion stars flicker rapidly; others sit almost still.

Orion stars occupy the early end of the majestic scale of stellar evolution. At the other end live more "eruptive" stars. The *novae* are hot dwarf stars whose brightness can increase to more than 15 magnitudes in a few days. Even old novae sputter from time to time, so keep an eye on your favorites.

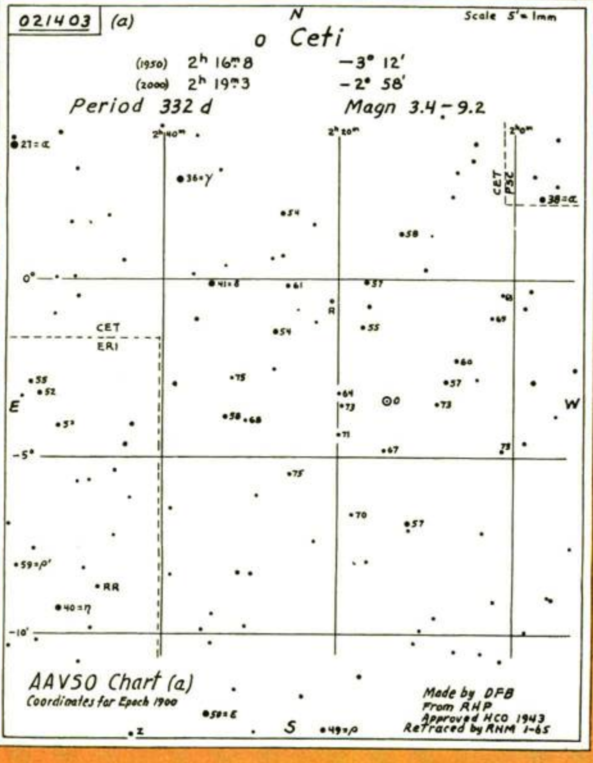
The most common novae increase rapidly — mere days to rise to maximum brightness — then slowly dim. There are also novae whose decline and fall take up to half a year to drop two magnitudes, while other novae are so slow that their maximum brightness is maintained for many years.

What about recurrent novae, stars like T Coronae Borealis? These are stars where more than one outburst has been observed. And who knows — maybe all novae recur. There is even a class of novae which are not novae (hi there, P Cygni!), but only act like novae.

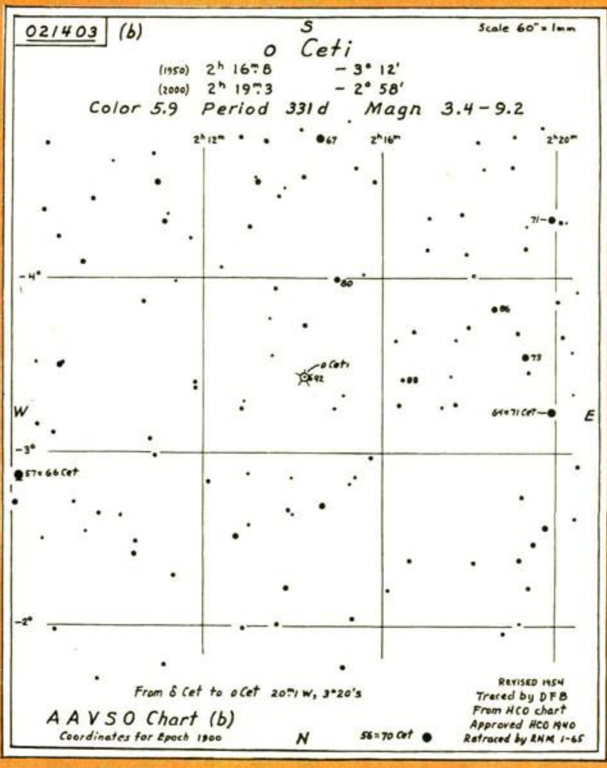
Some stars erupt and get brighter; others dim suddenly. R Coronae Borealis heads a class of "reverse novae." These stars unexpectedly drop by up to eight magnitudes, then they begin a slow recovery. Other stars like exploding so much that they repeat their tantrums over and over again every few months. These are the famous *dwarf novae*. SS Cygni best represents them and is, in fact, the most popular non-regular star on the AAVSO's observing program. After you've had practice watching regular stars, try estimating SS Cyg, too.

Do SS Cyg stars offer sub-class surprises? Yes, they sure do. Within their ranks are the mysterious *Z Camelopardalis* stars. These explode, too, but sometimes get stuck on their way down to minimum brightness. Sometimes, I want to give them a long-distance nudge. Once I watched Z Cam remain constant, halfway between maximum and minimum, for over two years.

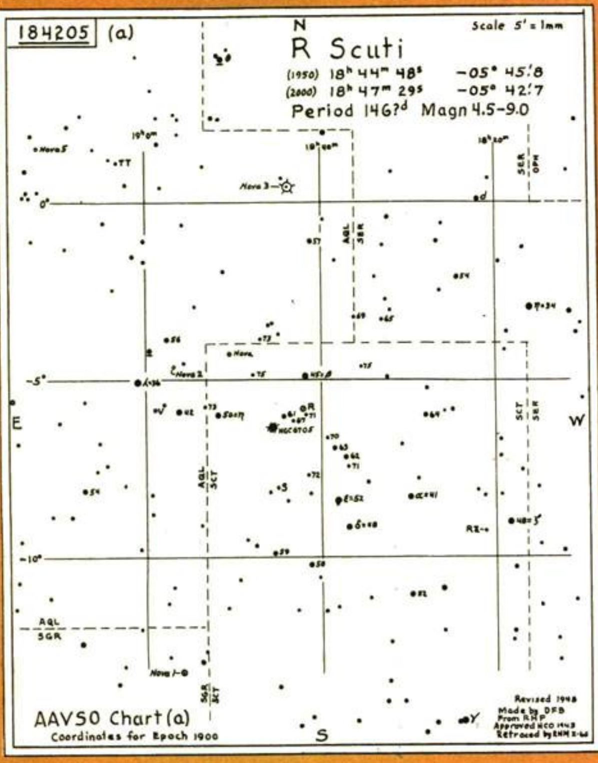
The swan song of all eruptive stars lies in the outburst of a supernova — a massive, red giant star whose colossal outburst expends much of its mass.


021403 (a)
N
Scale 5'=1mm
o Ceti
(1950) 2h 16m8 −3° 12'
(2000) 2h 19m3 −2° 58'
Period 332 d
Magn 3.4−9.2
2h40m
2h20m
2h0m
21=α
36=γ
38=α
CET
PSC
CET
ERI
0°
−5°
−10°
E
W
R
RR
40=η
59=ρ'
AAVSO Chart (a)
Coordinates for Epoch 1900
50=ε
S
49=ρ
Made by DFB
From RHP
Approved HCO 1943
Retraced by RHM 1-65

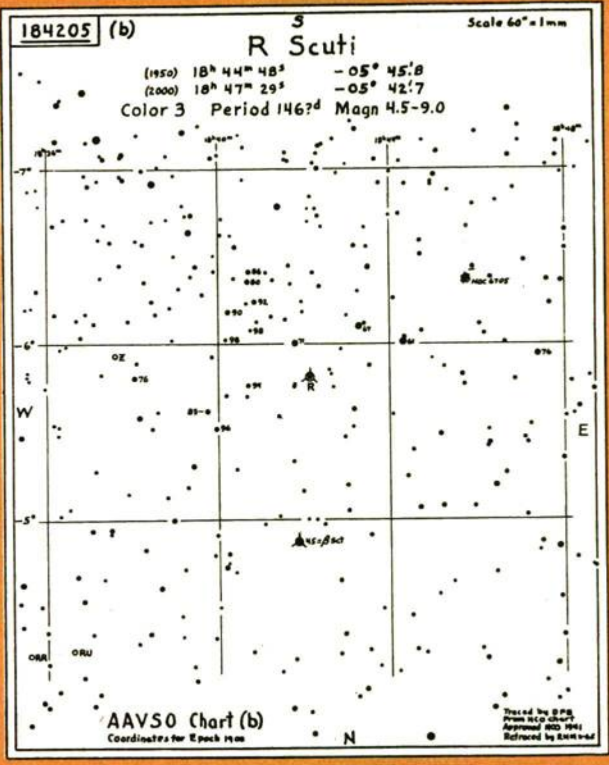
Omicron Ceti (naked-eye chart)


021403 (b)
S
Scale 60"=1mm
o Ceti
(1950) 2h 16m8 −3° 12'
(2000) 2h 19m3 −2° 58'
Color 5.9
Period 331 d
Magn 3.4−9.2
2h12m
2h16m
2h20m
−4°
−3°
−2°
W
E
o Ceti
64=71 Cet
57=66 Cet
From δ Cet to o Cet 20m1 W, 3°20's
AAVSO Chart (b)
Coordinates for Epoch 1900
N
56=70 Cet
Revised 1954
Traced by DFB
From HCO chart
Approved HCO 1940
Retraced by RHM 1-65

Omicron Ceti (binocular and telescope chart)


184205 (a)
N
R Scuti
Scale 5° = 1mm
(1950) 18h 44m 48s -05° 45.'8
(2000) 18h 47m 29s -05° 42.'7
Period 146?d Magn 4.5-9.0
E
W
S
AQL
SGR
SER
OPH
SCT
Nova 3
Nova 1
AAVSO Chart (a)
Coordinates for Epoch 1900
Revised 1948

R Scuti (naked-eye chart)


184205 (b)
S
R Scuti
Scale 60' = 1mm
(1950) 18h 44m 48s -05° 45.'8
(2000) 18h 47m 29s -05° 42.'7
Color 3 Period 146?d Magn 4.5-9.0
W
E
N
R
AAVSO Chart (b)
Coordinates for Epoch 1900

R Scuti (binocular and telescope chart)

For a few weeks, such a star may shine with the intensity of 10 billion Suns. None have been seen in our Galaxy for centuries, so we're long overdue.

Eclipsing Stars

An eclipsing binary star is a variable by coincidence. Just because Earth happens to be in line with the orbit of two stars, we observe a periodic drop in brightness as one star moves in front of the other. Algol, the "winking demon," typifies these. Eclipses take place at fixed intervals with longer periods of maximum brightness (from ⅕ day to 30 years) between drops. But *Beta Lyrae* stars are different — they're always going into or coming out of an eclipse, so they vary almost all the time.

So, how many types of variables are there? Plenty. And let's not forget variables which may not be variable at all. V Cephei, for instance, was *named* as a variable, but may never have varied in recorded history! It should still be watched closely, every century or so, for further signs of nonvariation.

Our galaxy of variables is vibrant and exciting. When you look at a variable star, you are actually seeing an example of the universe unfolding. Is it unfolding as it should? If we can look through a telescope and see it happen, then I guess it must be.

Observing Variable Stars

After you've observed your variable, then what? You could go inside and watch television, forgetting that what you just observed might aid, in a small way, the advance of science. Instead, I suggest that you record your observations — and not once, but three times.

The first record goes on a small notepad you bring out to your telescope. This piece of paper is every bit as important as your telescope's eyepiece, mirror, and mounting. On this paper, write down the estimate of every variable you observe on a particular night — and just on that night. Whatever you did during a previous session should be filed somewhere else. This night is new, your work is fresh, and you don't want to be influenced by observations from another time and place. On this paper record the time, name, and magnitude of each variable, as well as unusual circumstances that may have affected your observation.

Once your session at the telescope is finished, go inside and record your work again. This time, enter your observations using a system that lists each star separately. You may use carefully filed index cards, or a computerized listing. File the stars according to constellation or using their Harvard designation (a six-figure code that helps identify a star by its position in the sky). With record-keeping completed, you may want to compare your estimate with what you saw last week. Has the star changed significantly, getting either brighter or fainter, or is it just sitting there waiting for some unfathomable command? You should treat those simple numbers you obtained by observing with some respect, for they will teach you and other astronomers about the conduct of a star.

At the end of each month, it is time to tell the world what you have seen. Although there are a number of organizations that collect observations of variables, the most prominent is the American Association of Variable Star Observers, 187 Concord Ave., Cambridge, MA 02138. For almost three-quarters of a century (since its founding in 1911), this organization has encouraged and collected observations on all kinds of variables. It has produced thousands of accurate finder charts, including those shown here, each with carefully determined comparison star magnitudes to help you find and estimate your stars. All this work is done through the memberships of amateur stargazers like you and me. If you would like to know more, and feel serious about variable star observing after testing your skills on Delta Cephei, Omicron Ceti, and R Scuti, I recommend you join the AAVSO. The few stars in this article are just a mere trickle compared to the ocean of variables whose observation the AAVSO sponsors.

David Levy is a variable star observer and the author of two books, "The Joy of Gazing" and a forthcoming biography of Bart Bok.

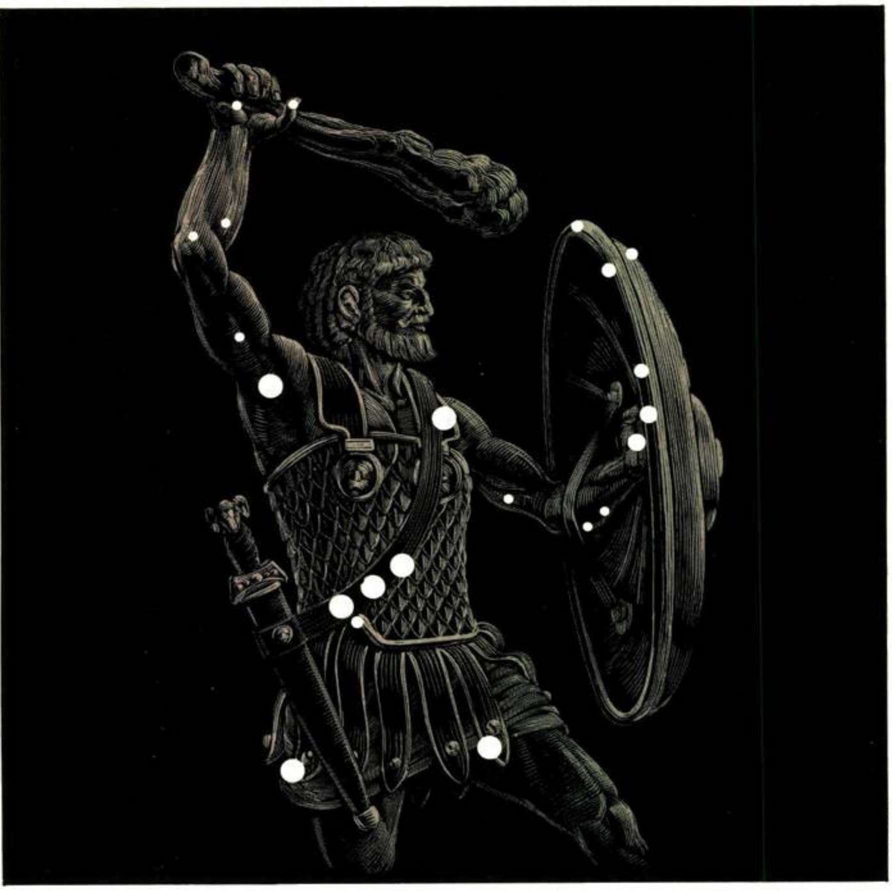
Left: Messier 42, the Orion Nebula, is one of the finest emission nebulae in the sky. Binoculars or finder telescopes show a one-degree patch of fuzzy light centered on the Hunter's Belt. Photo by Dennis Ratledge. Below left: Messier 78 is one of the sky's brightest reflection nebulae; M-78 appears as a circular patch of light containing three bright stars. Photo by Lee C. Coombs. Below right: The Horsehead Nebula is a small dark nebula backlit by a dim strip of emission nebulosity, making it very difficult to see. Photo by Scott Rosen.

Orion

Ori
Orionis

Lepus

Lep
Leporis



Keith Ward

The constellation Orion is one of the most familiar sights in the entire sky and its most famous inhabitant — the Orion Nebula — is one of the most familiar deep-sky objects. Orion, the Hunter, contains many other attractions, including some fine double stars and star clusters, as well as multitudes of faint nebulae. Its neighbor to the south, Lepus the Hare, is a rather overlooked group of stars which also houses fine objects for backyard deep-sky observers.

Orion's prime attraction is **M-42** (NGC-1976), the Orion Nebula, which is just visible to the unaided eye as a fuzzy patch in the Hunter's sword. When viewed with a small telescope, M-42 transforms into a glowing, greenish-white nebulosity spanning over one degree in diameter. Distinctly shaped, it resembles a giant, luminous fan. A larger telescope's low-power field of view reveals subtle gradations of light and dark patches, and streamers of bright nebulosity so detailed that it is impossible to adequately describe or sketch.

The total magnitude of M-42 is about 3.5, and its dimensions are 85′ x 60′. If the calculated distance of 500 parsecs is correct, M-42 measures some 10 parsecs across and could contain more than 20,000 solar systems stacked end to end! Glowing ionized gases energized by hot young stars in its central part produce the Orion Nebula's light. M-42 is a typical emission nebula; these contain mostly hydrogen, some helium and small amounts of carbon, oxygen, and nitrogen.

Embedded within M-42 is the multiple star **Theta^1** (θ^1) **Orionis**, otherwise known as the Trapezium for its trapezoidal shape. The Trapezium is the most observed quadruple star in the sky. Its members have magnitudes of 5.4 (star C: spectral type O6), 6.3 (star D: B0), 6.7-7.7 (star A: A7, eclipsing binary), and 8.0-8.7 (star B: eclipsing binary of uncertain spectral type). The separations are as follows: A-B is 8.7″, B-D is 19.2″, D-C is 13.3″, and C-A is 12.9″. A small telescope easily resolves Theta^1, showing the four brilliant white components.

North of M-42 and visible within the same low-power field is the bright nebula **M-43** (NGC-1982), which looks like a bloated comma. An eighth-magnitude star within M-43 illuminates it, but the nebula's surface brightness makes it easily visible. M-43 doesn't show as much range in brightness or detail as M-42, but it has a bright ring around the star which in turn is surrounded by fainter nebulosity. M-43 is actually a piece of the Orion Nebula, seemingly detached because a dark nebula obscures their connection.

A Moon's diameter to the south of Zeta (ζ) Orionis, the easternmost star in the Hunter's Belt, is the famous dark nebula **Barnard 33**. This object is silhouetted against the bright nebula IC 434 and is best known as the Horsehead Nebula. Unlike M-42 and M-43, B33 is *very* difficult to see in backyard telescopes — its small size (5′) and low contrast against IC 434 conspire to make it a tricky target. Success in observing the Horsehead varies greatly and depends mainly on sky conditions and the skill of the observer. Some have seen it using a 5-inch wide field refractor, while others have failed to locate B33 even with a 40-inch telescope!

Moving north to Zeta, we find the bright nebulosity **NGC-2024** just east of the star in the same low-power field. NGC-2024 is a large, detailed nebula which shows up fairly well in telescopes of 6-inches or more aperture, despite considerable interference from second-magnitude Zeta. The nebula's most striking feature is a broad, dark band which conspicuously bisects the 20′ diameter circular disk. Using high power (which removes Zeta from the field), many observers report seeing subtle bright and dark patches. Under a dark sky, NGC-2024 is one of the finest emission nebulae in Orion — imagine how spectacular it would look if it wasn't located next to second-magnitude Zeta!

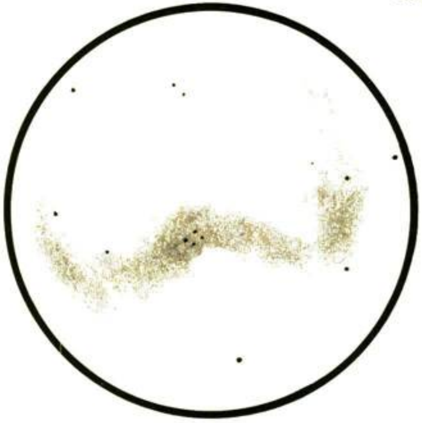
A curious planetary nebula in Orion is **NGC-2022** — a tiny disk of light measuring only 25″ across. The total magnitude of this object is only about 12, making it difficult to find in the starfield. To locate NGC-2022, wait for good conditions and use relatively high power to determine which "star" is actually a disk; under great skies with lots of magnification, you may even pick out the 14th magnitude central star.

One of the sky's easiest-to-observe reflection nebulae is bluish **M-78** (NGC-2068), which lies northeast of

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

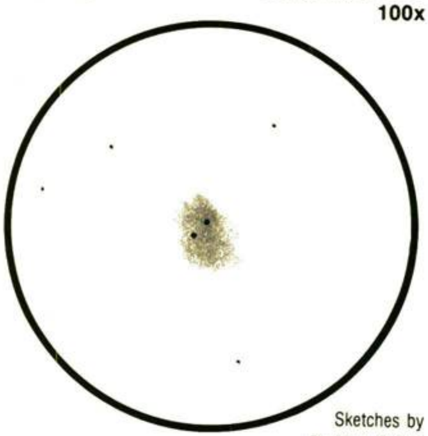
M-42

8-inch f/10 SCT
50x

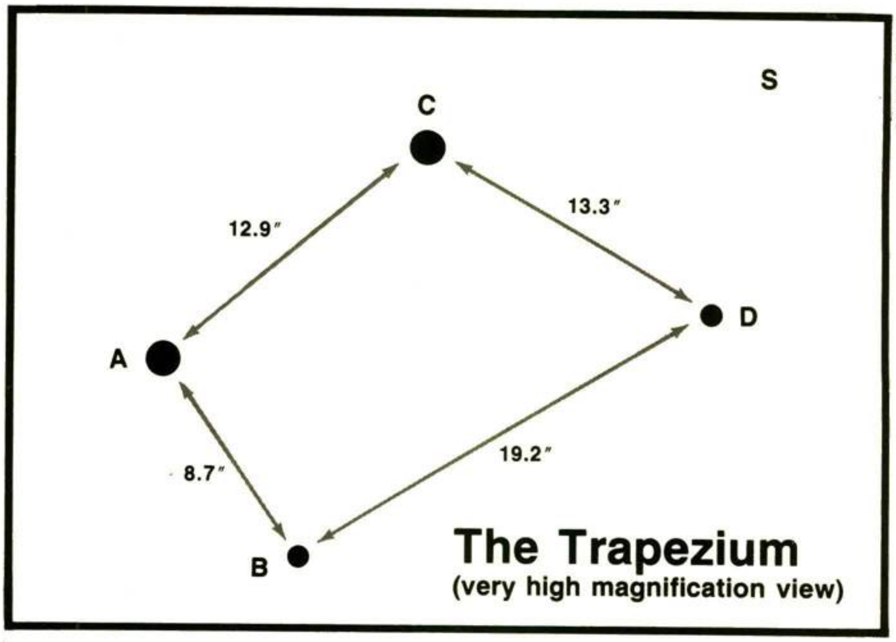


M-78

8-inch f/10 SCT
100x



Sketches by
David J. Eicher



The Trapezium
(very high magnification view)

David J. Eicher

Orion's Belt. This nebulosity shines not by fluorescence, as do emission nebulae, but by starlight reflected off dark grains of material — that's why so few reflection nebulae are bright enough to observe with backyard equipment. At its distance of 500 parsecs, it's amazing we can see M-78 so well. The nebula measures 8′ x 6′ across — about the same size as the Crab Nebula in Taurus — and contains three bright stars, all of which contribute light to the nebula. A good 4-inch reflector at 100x shows a patch of light so subtle it appears like breath on a mirror; a 10-inch reflector reveals an elongated shape in M-78 and easily shows 5′ worth of nebulosity. North of M-78 in the same field is **NGC-2071**, a detached piece of nebulosity which shows up almost as well as M-78 itself.

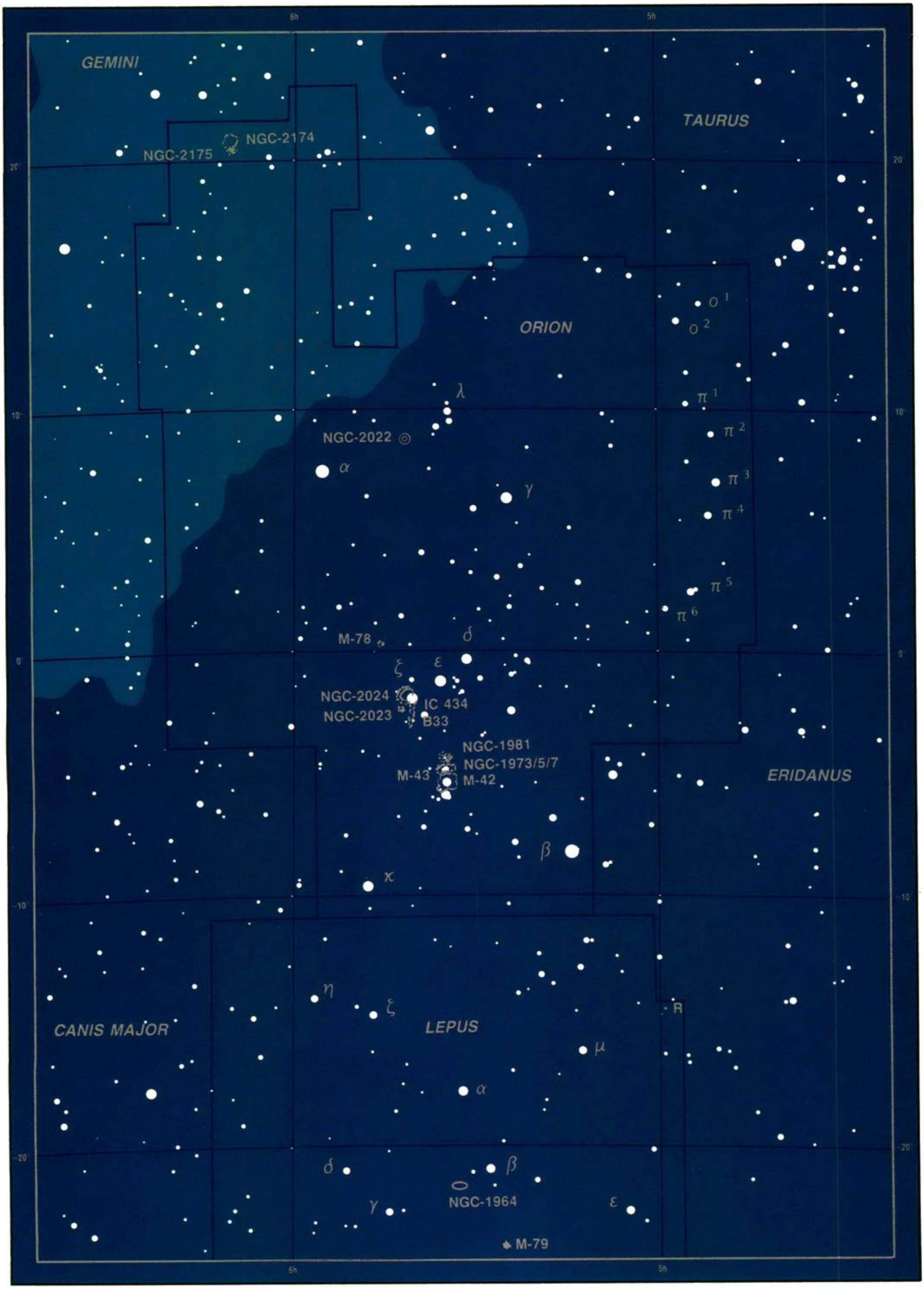
High up in Orion's northernmost reaches, near the star cluster M-35 in Gemini, is an unusual pair of deep-sky objects: **NGC-2174** is a faint ruddy emission nebula surrounding the bright open cluster **NGC-2175**, which is easily visible in binoculars. Small telescopes show the latter as a condensed cluster of tiny stars that appear grainy. Large amateur telescopes operating under dark skies also show NGC-2174 as a fan-shaped nebulosity spanning some 25′.

The constellation Lepus contains two objects of interest to deep-sky observers. The first is **M-79** (NGC-1904) — one of the finest globular clusters visible during the winter. This fine object shines at magnitude 8.4 and measures 7.5′ across and is easily visible as a fuzzy spot in binoculars or finderscopes. Small telescopes show a hazy, unresolved ball of light with a golden-yellow color; backyard scopes in the 12-inch to 20-inch class resolve M-79's outer edges, confirming its stellar composition. Lepus also contains the bright galaxy **NGC-1964** — a magnitude 11.8 Sb-type spiral measuring 5.0′ x 1.6′ across. Its nearly edge-on angle allows us an oblique view of the galaxy's hub and core, but doesn't reveal much of NGC-1964's spiral arms. The very largest backyard telescopes, under near-perfect conditions, may show the faintest hint of detail within this distant spiral.

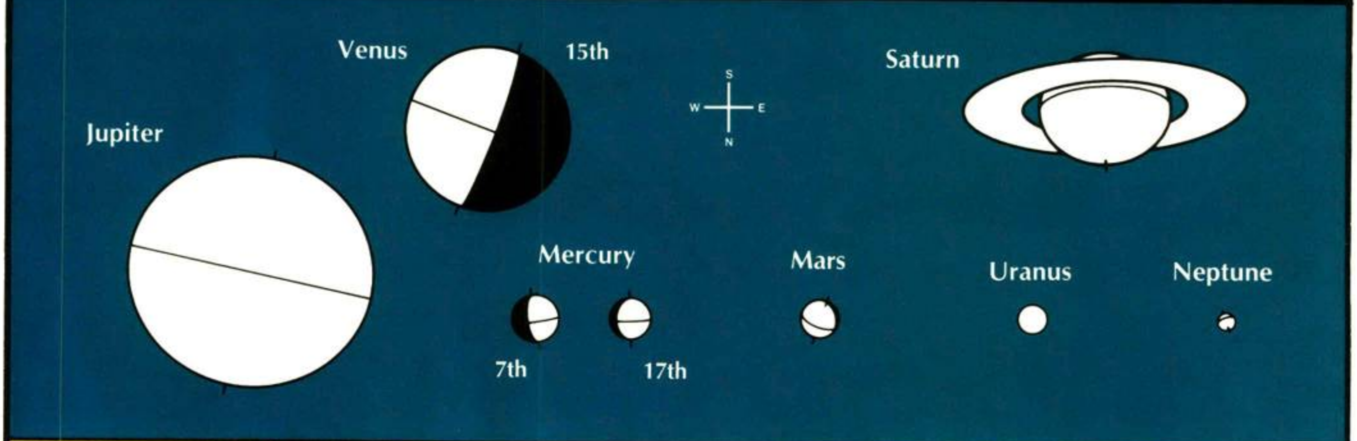
Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	N★	Mag.★
R Lep		LPV	4h 59.5m	−14°49′	5.9↔11.0	432d		
Rigel (β Ori)		★^{2}	5h 14.5m	−08°12′	0.1,6.7	9.4″		
NGC-1904	M-79	●	5h 24.3m	−24°31′	8.4	7.5′		
NGC-1964		§	5h 33.3m	−21°57′	11.8	5.0′x1.6′		
θ^1 Ori		★^{4}	5h 35.3m	−05°23′	5.4,6.3, 6.8,7.0	13.3″,19.2″, 8.7″,12.9″		
NGC-1976	M-42	☐E	5h 35.4m	−05°23′	3.5	85.0′x60.0′		
NGC-1973/5/7		☐R	5h 35.5m	−04°50′	—	45.0′x35.0′		
NGC-1981		⊙	5h 35.5m	−04°22′	8.0	18′	45	8....
NGC-1982	M-43	☐E	5h 35.5m	−05°16′	9.0	10′x5′		
IC 434		☐E	5h 41.1m	−02°25′	—	60′x10′		
Barnard 33		☐D	5h 41.2m	−02°31′	—	5′		
NGC-2022		■	5h 42.0m	+09°04′	12.3p	28″x27″		
NGC-2023		☐R	5h 41.7m	−02°14′	—	10′		
NGC-2024		☐E	5h 41.9m	−01°51′	—	30.0′		
NGC-2068	M-78	☐R	5h 46.7m	+00°03′	11.0	8.0′x6.0′		
NGC-2174/5		⊙☐E	6h 09.7m	+20°30′	—	25′	—	8....

N★ = number of stars, Mag.★ = magnitude range of cluster or magnitude of central star, (...) indicates many fainter.

★^{2}	*Double Star*
★^{4}	*Quadruple Star*
LPV	*Long Period Variable*
⊙	*Open Star Cluster*
●	*Globular Star Cluster*
■	*Planetary Nebula*
☐E	*Emission Nebula*
☐R	*Reflection Nebula*
☐D	*Dark Nebula*
§	*Spiral Galaxy*

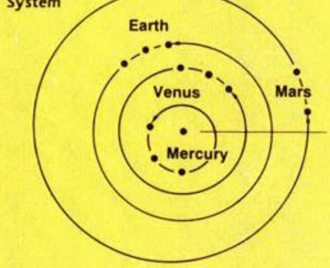

6h
5h
GEMINI
TAURUS
NGC-2174
NGC-2175
20°
ORION
o 1
o 2
λ
π 1
10°
π 2
NGC-2022
α
π 3
γ
π 4
π 5
π 6
M-78
δ
0°
ζ
ε
NGC-2024
IC 434
NGC-2023
B33
NGC-1981
NGC-1973/5/7
M-43
M-42
ERIDANUS
β
κ
-10°
η
ζ
R
CANIS MAJOR
LEPUS
μ
α
-20°
δ
β
NGC-1964
γ
ε
M-79
6h
5h

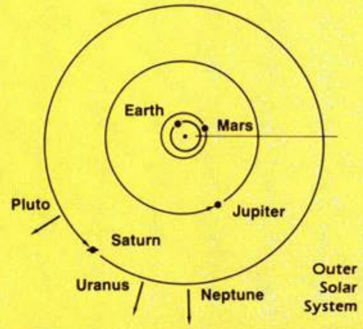
Planetary Data January 1985


Venus
15th
Jupiter
S
W
E
N
Saturn
Mercury
7th
17th
Mars
Uranus
Neptune

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.6′	—	0.98	—	—	280°31.5′	18h 46.7m	−23°00.6′
		15	−26.8	32.6′	—	0.98	—	—	294°47.4′	19h 47.7m	−21°08.2′
		31	−26.8	32.5′	—	0.99	—	—	311°04.1′	20h 54.9m	−17°23.9′
Mercury	☿	1	−0.2	7.0″	57%	0.96	0.38	176°03.0′	257°37.6′	17h 09.5m	−20°43.6′
		15	−0.3	5.6″	82%	1.21	0.45	224°11.5′	273°50.4′	18h 19.7m	−23°11.1′
		31	−0.5	4.9″	94%	1.36	0.46	268°58.8′	297°28.0′	20h 02.3m	−22°04.1′
Venus	♀	1	−4.3	19.8″	61%	0.84	0.72	43°46.3′	325°50.0′	21h 57.4m	−14°08.8′
		15	−4.4	22.5″	55%	0.74	0.72	66°14.8′	341°10.9′	22h 54.0m	− 7°39.5′
		31	−4.5	26.8″	46%	0.62	0.72	92°03.0′	357°12.4′	23h 51.0m	0°10.4′
Mars	♂	15	1.0	5.2″	92%	1.81	1.41	18°35.1′	345°20.3′	23h 09.7m	− 6°11.9′
Jupiter	♃	15	−1.9	32.1″	100%	6.13	5.15	294°43.7′	294°14.9′	19h 47.7m	−21°24.9′
Saturn	♄	15	0.6	15.9″	100%	10.39	9.91	231°05.6′	235°28.7′	15h 37.5m	−17°15.1′
Uranus	⛢	15	5.7	3.5″	100%	19.81	19.05	254°17.2′	255°38.6′	17h 00.6m	−22°44.7′
Neptune	♆	15	8.0	2.2″	100%	31.16	30.26	271°17.2′	271°31.3′	18h 09.5m	−22°18.7′
Pluto	♇	15	13.8	0.1″	100%	29.93	29.79	212°39.6′	214°07.4′	14h 32.3m	2°36.8′

Inner Solar System

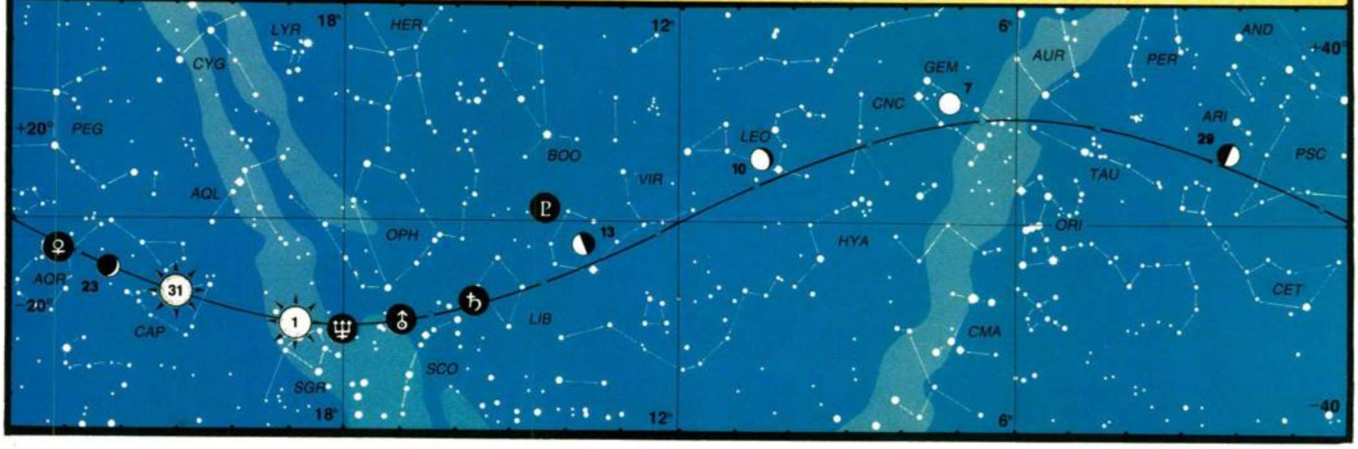

Earth
Venus
Mars
Mercury


Earth
Mars
Jupiter
Pluto
Saturn
Uranus
Neptune

Outer Solar System

Moon Data

Full Moon	Jan. 7 at 2h16m
Last Quarter	Jan. 13 at 23h27m
New Moon	Jan. 21 at 2h28m
First Quarter	Jan. 29 at 3h29m
Full Moon	Feb. 5 at 15h19m
Last Quarter	Feb. 12 at 7h51m
Perigee: Jan. 12 at 3h26m	369,590 km.
Apogee: Jan. 27 at 9h32m	404,641 km.


LYR
18°
HER
12°
6°
AUR
AND
+40°
CYG
GEM
PER
7
CNC
+20°
PEG
ARI
LEO
29
PSC
BOO
10
VIR
TAU
AQL
♇
13
OPH
HYA
ORI
♀
AQR
23
31
CET
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SGR
18°
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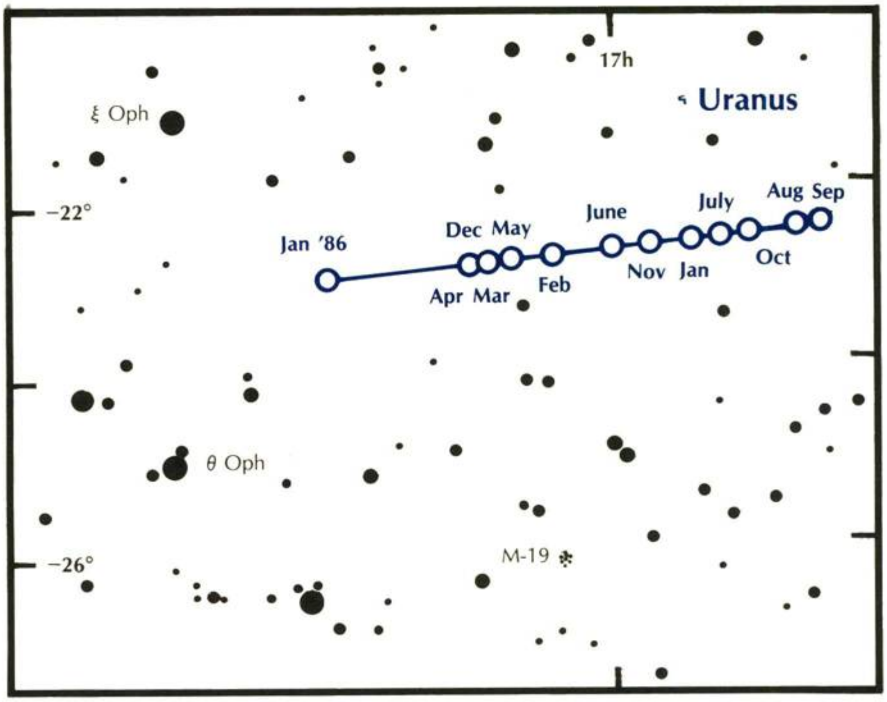
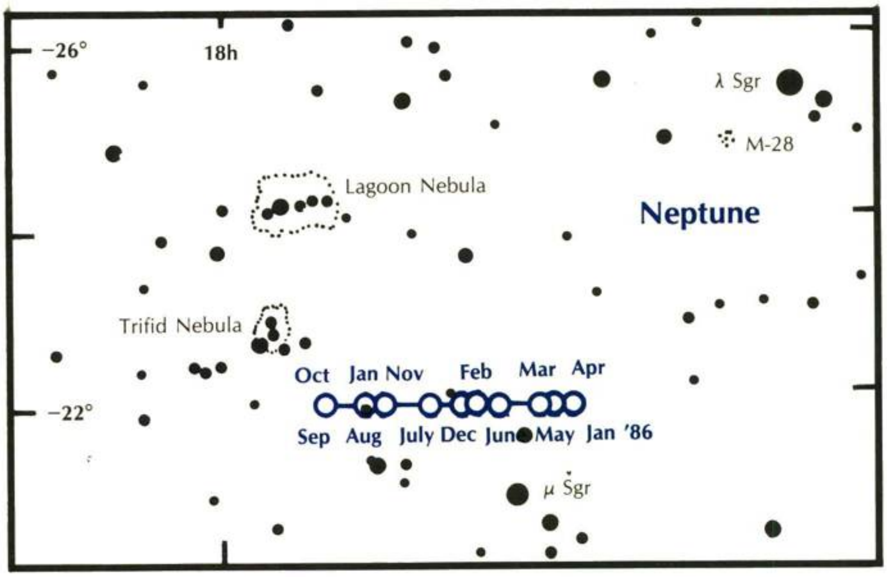
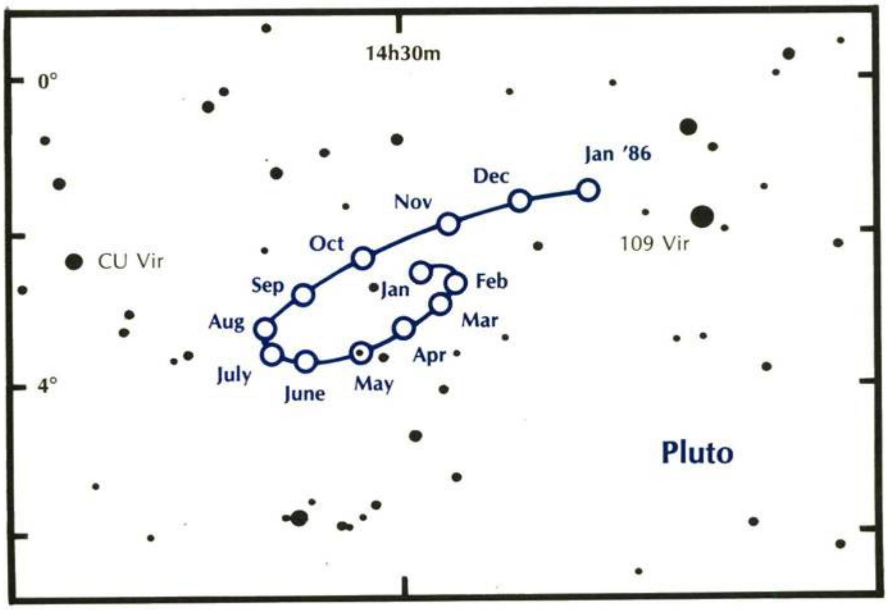
6°
−40


ξ Oph
17h
Uranus
−22°
Aug Sep
July
June
Dec May
Jan '86
Oct
Nov Jan
Feb
Apr Mar
θ Oph
M-19
−26°


−26°
18h
λ Sgr
M-28
Lagoon Nebula
Neptune
Trifid Nebula
Oct Jan Nov Feb Mar Apr
−22°
Sep Aug July Dec June May Jan '86
μ Sgr


14h30m
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Jan '86
Dec
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Aug
Mar
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May
4°
Pluto

These diagrams show the movements of Uranus, Neptune, and Pluto for 1985. The circles mark the positions on the first of each month; the coordinate epoch is 2000.0. The Uranus chart has north at top (for use with binoculars); the charts for Neptune and Pluto have south at top to match telescopic views.

Mercury

On January 3rd, Mercury reaches greatest western elongation in the morning sky — the first of seven elongations this year (see box on page 84). Starting with an elevation of about 10° (45 minutes before sunrise), Mercury will settle lower toward the southeastern horizon during January mornings. The planet should remain visible telescopically, however, until about the 20th.

In your eyepiece, Mercury will be 7″ in diameter on the 1st; this will shrink to 5.3″ on the 21st, while its apparent phase will round out from 57% lit to 88%. The planet will brighten imperceptibly from −0.2 magnitude on the 1st to −0.3 on the 21st.

Mercury's next apparition will be in the evening sky, with greatest elongation on March 17th.

Venus

Venus' greatest visibility this year will be during January, February, and the first part of March (greatest eastern elongation is on January 22nd) when it's high in the west-southwest during the hour after sunset. These next three months will be the most exciting part of Venus' long evening apparition, which began last July.

In your telescope, you'll see Venus grow from 20″ across and 60% lit on January 1st to an enormous skinny crescent, 59″ across and 1% lit, by April 1st. The planet is racing toward inferior conjunction, when it will pass between the Earth and Sun. As Venus nears us, it is turning more and more of its nightside hemisphere toward our view; it is also, naturally, growing larger in apparent size. Although you won't see changes occurring on a night-to-night basis, you *will* see differences from one week to the

Universal Time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times in The Backyard Astronomer are UT unless otherwise noted. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska, 9; and Hawaii, 10. For example, if an event is to happen at 03:00 hours UT on February 2, then EST for the event is 10 p.m., February 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m, March 4.

next. For a fascinating observing project, try sketching the eyepiece view (or photographing it) during the coming weeks.

Earth

Our planet reaches perihelion at 20h UT on January 3rd; we will then be 0.98221 astronomical unit (146.94 million kilometers) from the Sun.

Mars

Though overshadowed by Venus, Mars is relatively prominent in the evening sky. At 1.0 magnitude, it lies in the dim constellation of Aquarius, and appears as a ruddy-orange dot to the left of Venus. On January 15th, Mars is a little more than 1.8 AUs away; given the planet's actual size, this yields an apparent disk only 5.2″ across.

Asteroids

1 Ceres (magnitude 7.7) crosses into Aries from Cetus early in January. On the 2nd, it is stationary and then begins moving northeastward. Its positions:

9th: 2h 42m 41s, 11° 3.1′
19th: 2h 45m 34s, 11° 59.8′

Ceres sets around 1 a.m. local time on January 15th.

2 Pallas (9.9) is traveling eastward in Aquarius. Its positions:

9th: 23h 13m 16s, −10° 15.1′
19th: 23h 25m 8s, − 9° 45.8′

Pallas sets about 9:30 p.m. local time on the 15th.

3 Juno (10.3) crosses the ecliptic northbound near the first of the year and heads eastward in central Virgo. Its positions:

9th: 12h 43m 59s, −4° 30.9′
19th: 12h 48m 49s, −4° 26.3′

Juno rises around 11:30 p.m. local time on the 15th.

4 Vesta (7.7) is also in Virgo, about 15° east and 2° or 3° north of Juno. Its positions:

9th: 13h 40m 57s, −2° 39.0′
19th: 13h 53m 26s, −3° 15.9′

Vesta rises about 12:30 a.m. local time on the 15th.

To facilitate plotting their positions on a star atlas, all asteroid coordinates are for the epoch 2000.0.

Jupiter

Jupiter is in conjunction with the Sun on January 14th. Although briefly visible to the naked eye in the evening sky at the beginning of January and also in the morning sky by month's end, it'll be too low for good telescopic viewing all month.

Saturn

Saturn will be a clearly visible yellowish-white "star" in Libra during January. Well up in the southeastern sky by sunrise, Saturn provides a fine sight in telescopes at moderate power. The slowly-increasing tip of the rings (23.5° on the 15th) has all but hidden Saturn's southern polar regions. During moments of steady seeing, you'll be able to discern some banding on the planet's ball and at least one dark streak in the rings — the Cassini Division.

On January 2nd at about 5h30m UT, the center of Saturn will pass 9′50″ south of the 5.5 magnitude star Zeta (ζ) Librae. You'll get a good view of the star and planet together using low to moderate-power eyepieces on your telescope.

Uranus

The finder chart on page 83 shows where Uranus will be relative to the stars of southern Ophiuchus this year. Unfortunately, since it was in conjunction with the Sun on December 5th — and because it has a −22° declination — Uranus still hasn't gained much elevation in the morning sky. On the 1st, it is 10° high, 45 minutes before sunrise; by the 31st, it will have only twice that elevation at the same time of day. Given that it's a sixth-magnitude object, you'll find Uranus easier to locate in February when its elevation is higher.

Right: The grand pinwheel of M-51, the Whirlpool Galaxy, in Canes Venatici is easy to find, being located 3° southwest of Benetnash, the last star in the Big Dipper's handle. Alexander Brownlee wins January's "Best Astro-Photo" award for this photo taken with a 16-inch f/5 Newtonian, hypered 2415, and a 90-minute exposure. Above: NGC-891 in Andromeda by Paul Roques.

Elongations of Mercury & Venus — 1985

	Date	Altitude	Azimuth	Type & Extent of Elongation
Mercury	Jan. 3	9°	128°	West (morning sky), 23°
	Mar. 17	9°	273°	East (evening sky), 18°
	May 1	1°	87°	West (morning sky), 27°
	July 14	6°	284°	East (evening sky), 27°
	Aug. 28	7°	76°	West (morning sky), 18°
	Nov. 8	2°	235°	East (evening sky), 23°
	Dec. 17	10°	125°	West (morning sky), 21°
Venus	Jan. 22	33°	229°	East (evening sky), 47°
	June 12	17°	90°	West (morning sky), 46°

Altitudes and azimuths are given for 45 minutes after sunset (eastern elongations) or 45 minutes before sunrise (western elongations) as seen by an observer at 40° north latitude. In other latitudes the figures will vary slightly. North = azimuth 0° or 360°, east = 90°, south = 180°, and west = 270°.

Neptune

Neptune's 1985 finder chart is also on page 83 (along with Pluto's); its visibility in the morning sky is even worse than Uranus'. By the end of January, it is only 14° high (45 minutes before sunrise).

Meteors

January is Quadrantid month for meteor watchers, but this year's display will probably be poor because it is badly timed for North Americans. The peak of activity comes around 5h30m UT on the 3rd, slightly before the radiant rises for the East Coast and much longer before it rises for the other time zones. In addition, the waxing crescent Moon will light up the skies until it sets around 3:50 a.m. local time. Since morning twilight begins only a few hours later, you'll be lucky to spot 10 or 20 Quads at most before dawn.

Comet Halley

At present, the comet lies in northern Orion. On the 15th, it will be 4.3 AUs from Earth with a magnitude of 16.5. Comet Halley's positions (epoch 2000.0 coordinates) are:

10th: 5h 36m 16s, 12° 10.6′
20th: 5h 25m 44s, 12° 22.4′

On the 13th, the comet passes 1.1° north of the star Lambda (λ) Orionis.

CHALLENGER
7
CRIPPEN FABIAN HAUCK RIDE THAGARD

STS 7
Enlarged
to show
detail.

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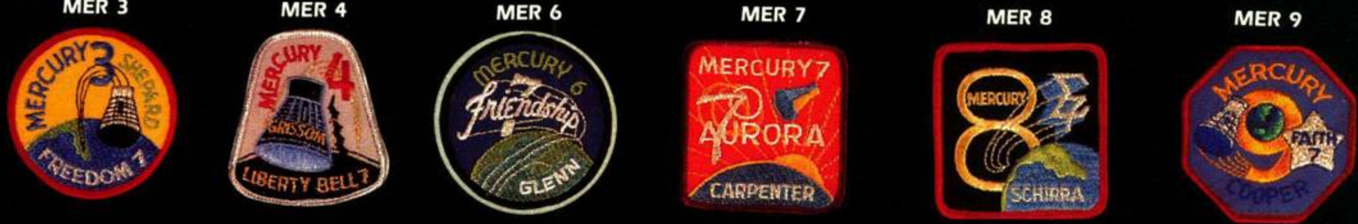
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MERCURY 3 SHEPARD FREEDOM 7
MERCURY 4 GRISSOM LIBERTY BELL 7
MERCURY 6 Friendship 7 GLENN
MERCURY 7 AURORA CARPENTER
MERCURY 8 SCHIRRA
MERCURY 9 FAITH 7 COOPER

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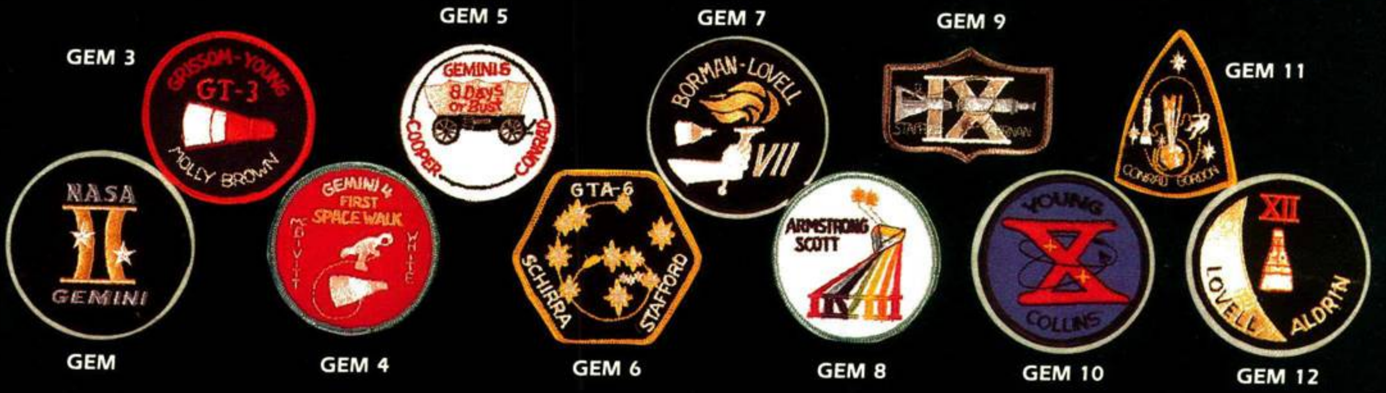
GEM 3 GEM 5 GEM 7 GEM 9 GEM 11
GEM GEM 4 GEM 6 GEM 8 GEM 10 GEM 12
GRISSOM-YOUNG GT-3 MOLLY BROWN
NASA II GEMINI
GEMINI 4 FIRST SPACE WALK McDIVITT WHITE
GEMINI 5 8 Days or Bust COOPER CONRAD
GTA-6 SCHIRRA STAFFORD
BORMAN-LOVELL VII
ARMSTRONG SCOTT
IX
YOUNG X COLLINS
CONRAD GORDON
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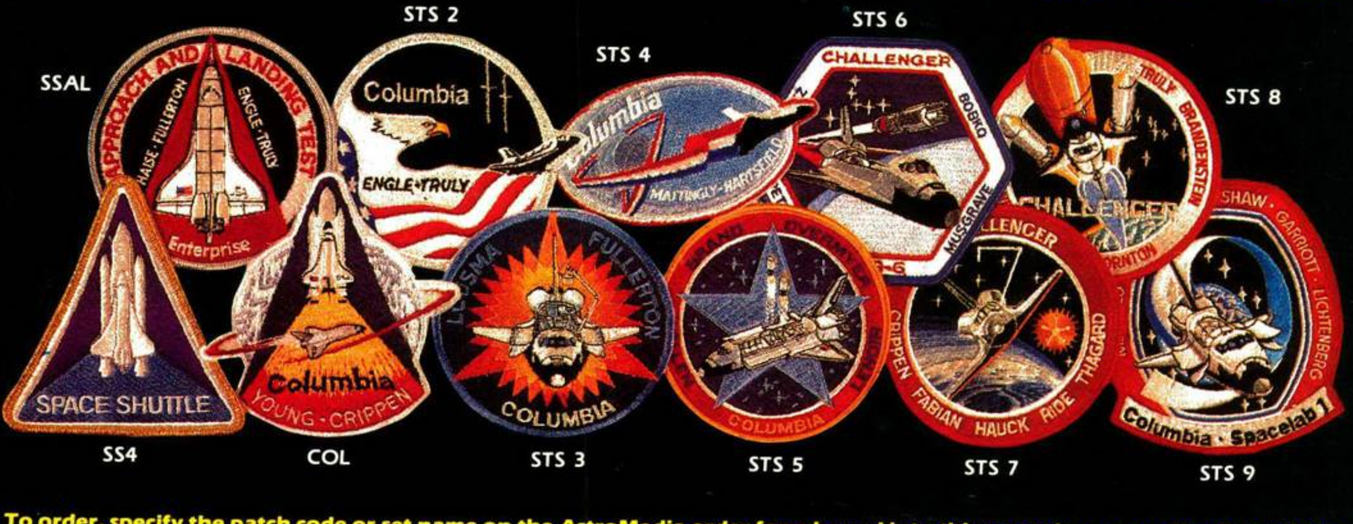
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SS4 COL STS 3 STS 5 STS 7 STS 9
APPROACH AND LANDING TEST HAISE-FULLERTON ENGLE-TRULY Enterprise
Columbia ENGLE-TRULY
Columbia MATTINGLY-HARTSFIELD
CHALLENGER BOBKO MUSGRAVE
TRULY BRANDENSTEIN CHALLENGER THORNTON
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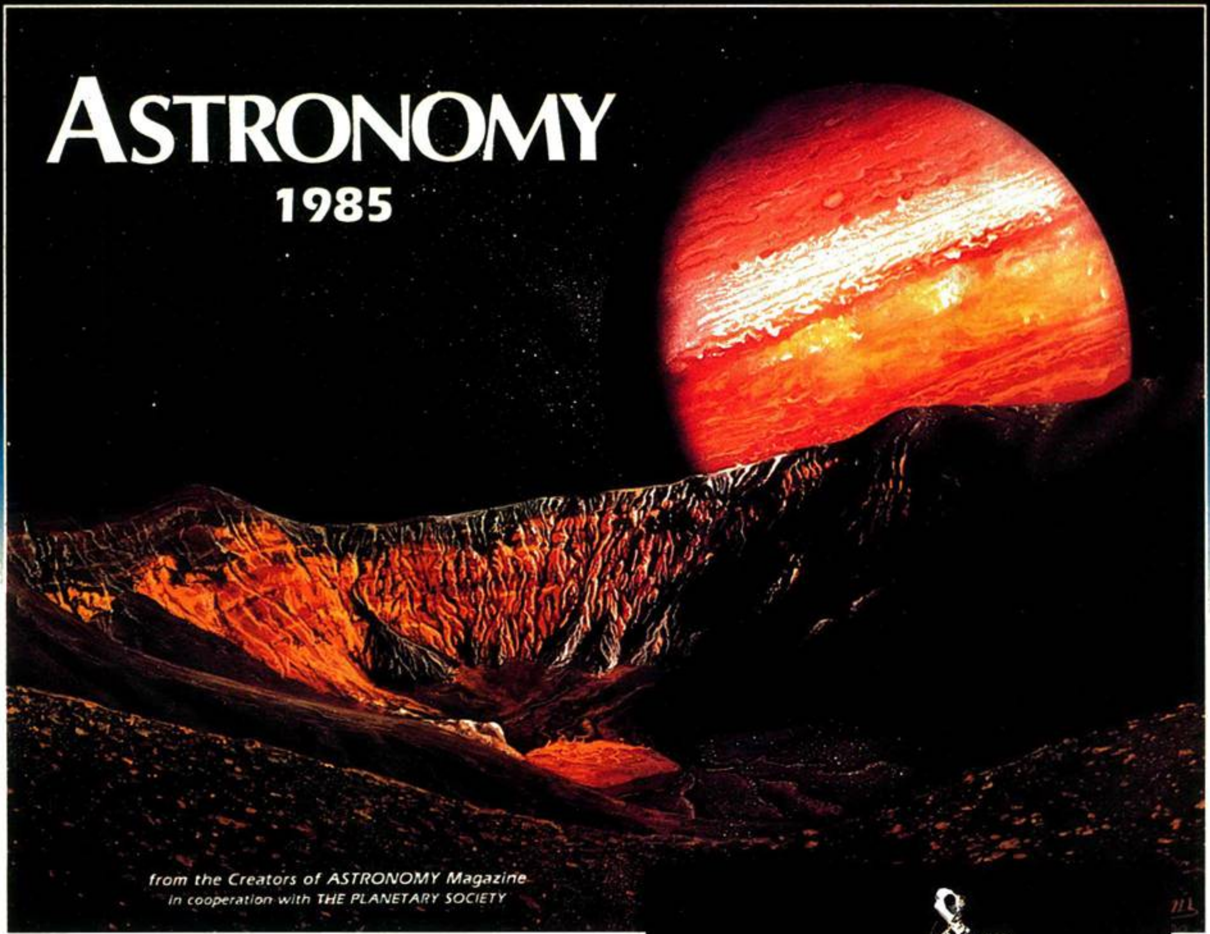
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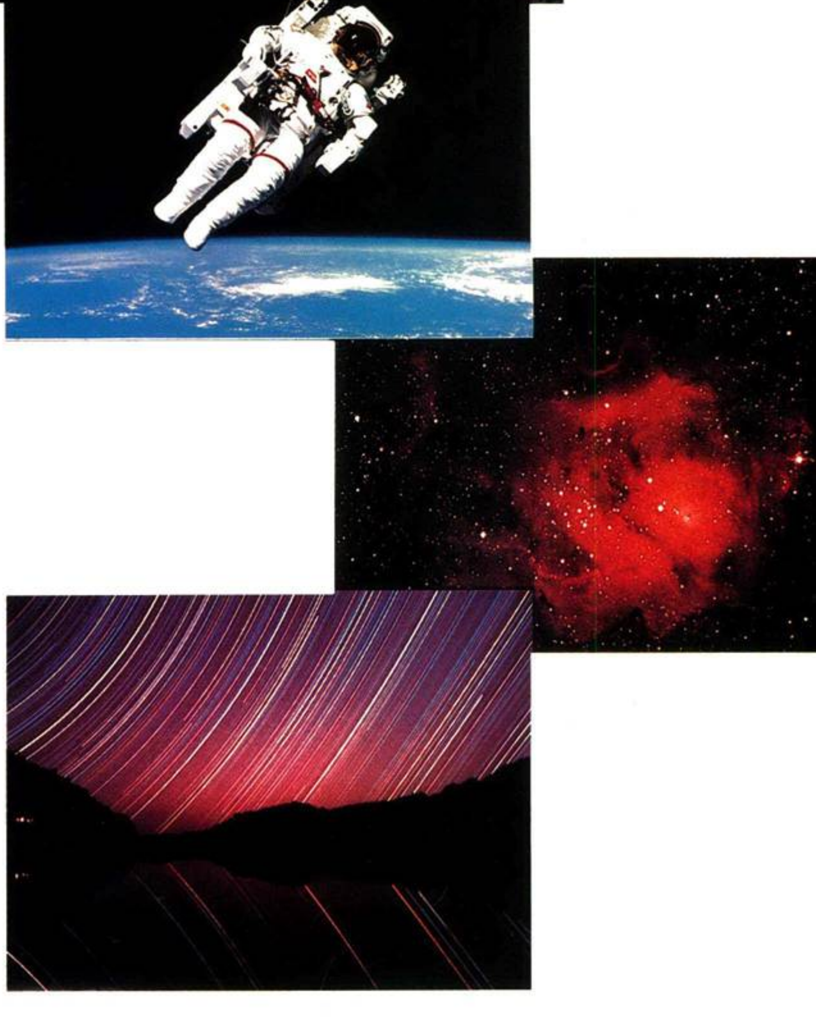

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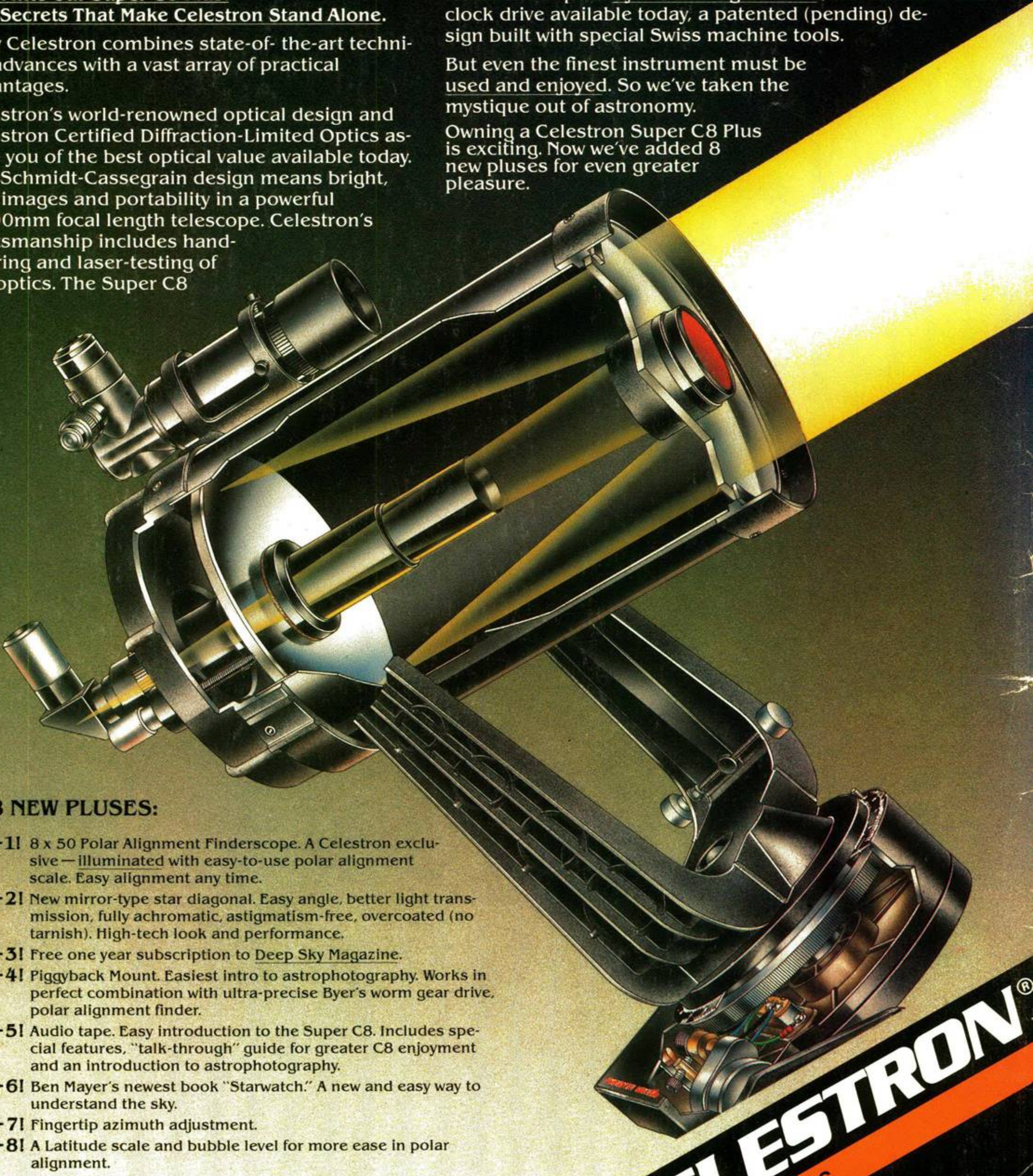

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